Case Narrative

Possible Mustard Release at Ukhaydir Ammunition Storage Depot

Case Narratives are reports of what we know today about certain events of the 1990-1991 Gulf War. This particular case narrative focuses on a possible chemical agent release resulting from Coalition bombings of the Ukhaydir Ammunition Storage Depot. This is an interim, not a final, report. We hope that you will read this and contact us with any information that would help us better understand the events reported here. With your help, we will be able to report more accurately on the events surrounding incidents reported in this narrative. Please contact my office to report any new information by calling:

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Ver 1.0

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Many veterans of the Gulf War have expressed concern that their unexplained illnesses may result from their experiences in that war. In response to veterans' concerns, the Department of Defense established a task force in June 1995 to investigate incidents and circumstances relating to possible causes. The Office of the Special Assistant to the Deputy Secretary of Defense for Gulf War Illnesses assumed responsibility for these investigations on November 12, 1996, and has continued to investigate reports of chemical warfare agent incidents.

To inform the public about the progress of these efforts, the Department of Defense is publishing on the Internet and elsewhere accounts that may contribute to the discussion of possible causes of illnesses of Gulf War veterans, along with documentary evidence or personal testimony used in compiling the accounts. This narrative is such an account.

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I. METHODOLOGY

One prominent hypothesis about illnesses among Gulf War veterans is that some of the reported symptoms are the result of exposure to chemical warfare agents. During and after the Gulf War, some veterans reported that they had been exposed to chemical warfare agents. To investigate these incidents, and to assess the likelihood that chemical warfare agents were present in the Gulf, the Department of Defense developed a methodology for investigation and validation based on work done by the United Nations and the international community. The criteria include:

- A detailed written record of the conditions at the site;
- Physical evidence from the site such as weapons fragments, soil, water, vegetation or human/animal tissue samples;
- A record of the chain of custody during transportation of the evidence;
- The testimony of witnesses;
- Multiple analyses; and
- A review of the evidence by experts.

While the methodology (Tab C) used to investigate suspected chemical warfare agent incidents is based on these protocols, the passage of time since the Gulf War makes it difficult to obtain certain types of documentary evidence, and physical evidence was often not collected at the time of an event. Therefore, we cannot apply a rigid template to all incidents, and each investigation must be tailored to its unique circumstances. Accordingly, we designed our methodology to provide a thorough, investigative process to define the circumstances of each incident and to determine what happened. Alarms alone are not considered to be certain evidence of chemical warfare agent presence, nor is a single observation sufficient to validate the presence of a chemical warfare agent.

After following our methodology and accumulating anecdotal, documentary, and physical evidence; after interviewing witnesses and key servicemembers; and after analyzing the results of all available information, the investigator assesses the validity of the presence of chemical warfare agents on the battlefield. Because we do not expect to always have conclusive evidence, we have developed an assessment scale (Figure 1) ranging from Definitely Not to Definitely, with intermediate assessments of Unlikely, Indeterminate, and Likely. This assessment is tentative, based on facts available as of the date of the report publication; each case is reassessed over time based on new information and feedback.

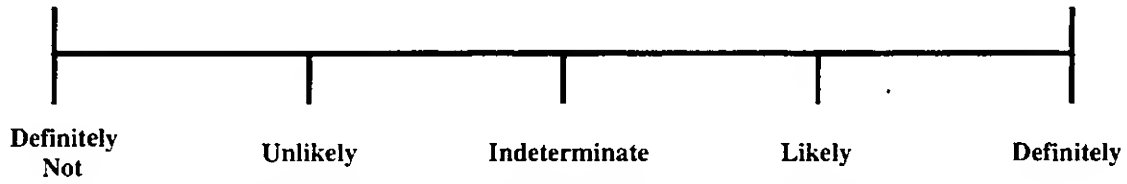

Figure 1. Assessment of chemical warfare agent presence

The standard for making the assessment is based on common sense: Do the available facts lead a reasonable person to conclude that chemical warfare agents were or were not present? When insufficient information is available, the assessment is Indeterminate until more evidence can be found.

As mentioned above, this methodology is designed to be adapted to individual case requirements. Most of our case narratives rely on the collection and analysis of information developed at the time of the Gulf War. However, events at Ukhaydir were not known until well after the end of the war. Therefore, the investigators were forced to rely on analysis conducted by multiple organizations over the last eight years. This case narrative is the result of close coordination between our investigators and analysts from the Central Intelligence Agency, the Defense Intelligence Agency, and the National Imagery and Mapping Agency. We also interviewed analysts from the United Nations Special Commission on Iraq (UNSCOM) knowledgeable about events at Ukhaydir. No Coalition personnel are believed to have been in the area of Ukhaydir during these events, so there are no medical reports to review. Similarly, because this case is the result of airstrikes deep in Iraq prior to the start of the ground war, there are no known first-hand witnesses available to interview.

The investigation of this case made use of work done by and information available throughout the Intelligence Community, including imagery analysis, a review of aircraft gun camera footage, hazard area modeling, mission data sheets, observed and modeled weather information, UNSCOM-provided information, and testimony before the Presidential Advisory Committee on Gulf War Veterans' Illnesses. What physical evidence there is for this case was discovered by UNSCOM personnel during inspections conducted under the auspices of United Nations Security Council Resolution 687. Although only UNSCOM inspectors have been given access to this physical evidence, our investigators have been able to learn about it through publicly-available UNSCOM reports.

II. SUMMARY

This report addresses the possibility that Gulf War Veterans may have been exposed to mustard agent released as a result of Coalition airstrikes at the Ukhaydir Ammunition Storage Depot located in Iraq. Our investigation to learn what happened at Ukhaydir during the Gulf War was an effort to determine if mustard agent could have been released and, if so, how much. Much of this information came from UNSCOM reports about their inspections in Iraq and their assessment of Iraq's movement of chemical weapons before, during, and after the Gulf War. Some of the information available has been contradictory and that has influenced our assessment of events. Using the assessment that mustard may have been released, our inquiry employed modeling and simulation to establish the potential extent of any hazard areas to determine if the possible mustard agent releases could have reached US forces.

From 1991 through 1996, Iraq presented three "Full, Final, and Complete" disclosures of its weapons of mass destruction programs. The third version, provided in 1996, stated that, during the Gulf War, 6,394 mustard-filled 155mm rounds had been stored at the Ukhaydir Ammunition

Storage Depot. In the first disclosure, released in spring 1991, Iraq had declared that 6,394 mustard-filled 155mm artillery rounds were located at the Fallujah Proving Ground southwest of Baghdad. In the fall of 1991, UNSCOM had inspected the rounds at the Fallujah Proving Ground and had accounted for 6,380, which included 117 green painted rounds, 107 of which had leaked, and 104 fire-damaged rounds, 94 of which had leaked.

As a result of the 1996 disclosure, United Nations' inspectors visited the Ukhaydir facility in spring 1997. While there, the inspectors discovered three additional intact mustard-filled 155mm rounds in debris around a repaired bomb crater. During a subsequent visit to Ukhaydir, later in 1997, UNSCOM inspectors discovered another intact mustard-filled 155mm round in the same area.

UNSCOM, using inspection data and the Iraqi disclosures, assessed in 1997 that the mustard-filled rounds inspected at the Fallujah Proving Ground had been stored at Ukhaydir during the Gulf War. The Intelligence Community (see glossary) reached the same conclusion. It was further assessed that the damage discovered in the rounds at the Fallujah Proving Ground may have occurred while the rounds were stored at Ukhaydir. Although Iraq had declared that no rounds had been damaged at Ukhaydir during the war, after an extensive investigation, that included a review of imagery, the Intelligence Community assessed that the damage could have occurred during two separate Coalition airstrikes—one on January 20, 1991, and a second on the night of February 13/14, 1991.

According to the 1997 Intelligence Community assessment, the January 20, 1991, strike caused an extensive fire that could have burned the 104 fire-damaged rounds and caused 94 of them to release their agent. Although they stated that it was possible the damage to the rounds did not occur at Ukhaydir, the Central Intelligence Agency (CIA) assessed that mustard agent could have been released but the large fire would have consumed most of it. The CIA's modeling indicated that any release would have fallen below the general population limit by the time it had gone 40 kilometers in any direction from Ukhaydir. This was hundreds of kilometers away from US troops located in Saudi Arabia.

The same 1997 Intelligence Community assessment placed the second strike at around midnight local time on February 13/14, 1991. To be conservative, they assumed that this strike may have destroyed as many as 11 mustard-filled rounds and possibly caused the 107 green rounds to leak after they fell into the resulting bomb crater. The CIA assumed for the purposes of modeling that the rounds unaccounted for by the UNSCOM inspections at the Fallujah Proving Ground and Ukhaydir were destroyed during the airstrike. The CIA and DoD both modeled this strike. The modeling produced hazard areas that did not extend further than 125 kilometers from Ukhaydir, still several hundred kilometers away from the known locations of US troops.

In 1998, UNSCOM returned to Ukhaydir partly to inspect 12 additional mustard-filled rounds excavated by Iraq and partly to perform a geophysical survey of the area where the rounds had been found. UNSCOM found no evidence of significant munitions debris or other evidence of chemical munitions destruction during this survey. In February 1999, the CIA sent a letter to DoD detailing the results of this UNSCOM inspection and providing a revised assessment of the

possibility mustard agent was released from Ukhaydir during the Gulf War. Both the CIA and UNSCOM continued to maintain that the rounds inspected at the Fallujah Proving Ground in 1991 were at Ukhaydir during the air campaign. However, in its letter, the CIA stated that it now believes a chemical agent release from Ukhaydir as a result of either airstrike is unlikely. The CIA based this new assessment on the lack of munitions debris or chemical contamination discovered during UNSCOM's 1998 inspection of Ukhaydir, and the fact that Iraq again re-iterated its claim that no rounds were damaged at Ukhaydir during the Gulf War.

In October 1999, the CIA sent a second letter to DoD discussing possible explanations, other than the bunker fire at Ukhaydir, for the fire-damaged rounds discovered by UNSCOM at the Fallujah Proving Ground in 1991. The CIA letter stated that the damaged rounds definitely released their agent, but the agency did not have specific information about where or when.

We have two assessments about events at Ukhaydir. The first is an assessment of whether there was any release. The second, more important assessment is whether any US troops were exposed to chemical agent. For the January 20, 1991, bunker fire, contradictory information about whether there was any release makes it impossible to determine if any mustard agent was released. Consequently, until additional information becomes available, our assessment of whether there was any release is indeterminate. However, even if there was a release, the modeling conducted by the CIA in 1997 shows that very little mustard agent would have survived the fire, and what did survive and escape into the atmosphere would not have exceeded the general population limit (the average concentration below which the general population could remain indefinitely with no effects) beyond a 40 kilometer radius from Ukhaydir. Because US troops were located hundreds of kilometers away along the Saudi Arabian border, we assess it as unlikely that any were exposed to mustard agent as a result of the airstrike on January 20, 1991.

For the February 13/14, 1991, strike, we also have contradictory information. As with the January 20th bunker fire, without additional information, it is impossible to determine if any mustard agent was released. Therefore, until additional information becomes available, the assessment of whether there was a mustard release is indeterminate. However, in 1997, based on the possibility the airstrike had struck the munitions, we simulated a release. We used source terms that took into account both the rounds missing at the time of UNSCOM's first inspection of Ukhaydir and the 107 empty green rounds found at the Fallujah Proving Ground. The modeling results predicted hazard areas that did not extend further than 125 kilometers from Ukhaydir, well away from the known locations of US troops hundreds of kilometers away. Therefore, we think it unlikely that any US troops were exposed to mustard agent from the airstrike on February 13/14, 1991.

III. NARRATIVE[1]

A. Background

Some people have theorized that US troops could have been exposed to chemical or biological agents as an indirect result of Coalition air attacks against Iraqi chemical and biological weapons facilities during the Gulf War air campaign.[2] As part of its effort to investigate suspected chemical and biological incidents, the Office of the Special Assistant to the Deputy Secretary of Defense for Gulf War Illnesses is examining the Coalition air campaign and chemical or biological warfare agent releases that may have occurred as a result of Coalition bombing. We have already released an information paper on the use of modeling and simulation in planning the air campaign[3] and a case narrative about the An Nasiriyah Southwest Ammunition Storage Point[4], where it is believed Coalition bombs did not damage any munitions. We are currently preparing separate papers analyzing events at Muhammadiyat and Al Muthanna, two storage points where Coalition bombs may have caused the release of chemical warfare agents.

This narrative discusses what we know about events at the Ukhaydir Ammunition Storage Depot during the Gulf War. During the Gulf War, the facility now referred to as Ukhaydir was known to the United States (US) as the Karbala Ammunition Storage Depot, after the name of the nearest town to the facility.[5] Ukhaydir is located approximately 100 kilometers southwest of Baghdad and approximately 250 kilometers due north of the Saudi Arabian border. (See Figure 2.) US air campaign planners targeted the facility as a chemical/biological site because they believed chemical or biological weapons could have been stored there.[6]

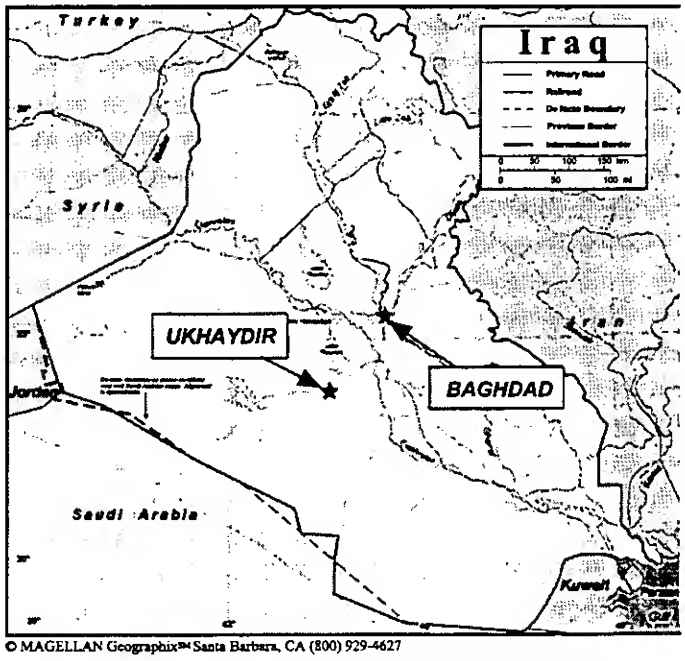

Figure 2. Ukhaydir Ammunition Storage Depot

[1] An acronym and abbreviation listing/glossary is at Tab A.

[2] Testimony of James J. Tuite before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, April 16, 1996.

[3] Special Assistant for Gulf War Illnesses, "The Use of Modeling and Simulation in the Planning of Attacks on Iraqi Chemical and Biological Warfare Targets" (Information Paper), February 23, 2000, web site www.gulflink.osd.mil/aircampaign/.

[4] Special Assistant for Gulf War Illnesses, "An Nasiriyah Southwest Ammunition Storage Point" (Final Report), January 10, 2000, web site www.gulflink.osd.mil/an_nasiriyah_ii/.

[5] Ukhaydir can also be spelled Al-Aukhader, Al Ukhaidar, Al Ukhaider, Al Ukhaydir, Aukhader, Aukhaider, Aukhaidir, and Ukhadir.

[6] Testimony of Robert D Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, July 30, 1997.

B. Iraq's Chemical Weapons Disclosures and UNSCOM Inspections Related to Ukhaydir

1. UNSCOM's Role

United Nations Security Council Resolution 687, which ended the Gulf War, also provided for the creation of the United Nations Special Commission on Iraq (UNSCOM). The United Nations created UNSCOM to

> render harmless, destroy or remove all of the agents and associated materials that were part of the Iraqi weapons of mass destruction program. This is [*sic*] chemical weapons, biological weapons and ballistic missiles with a range greater than 150 kilometers.... [Their] responsibility [was] to assure the Security Council, the U[nited] N[ations], that all Iraqi munitions and agents have been destroyed or accounted for.[7]

As part of these efforts, UNSCOM personnel conducted periodic inspection missions at both declared and suspected weapons of mass destruction production, storage, and research facilities in Iraq.[8]

The United Nation Security Council's resolution also required Iraq to make a full, final, and complete disclosure regarding its weapons of mass destruction programs.[9] Although this was intended to be a single, comprehensive document, to date Iraq has submitted three full, final, and complete disclosures, each more detailed than the previous.[10]

2. Iraq's 1991 Disclosure

After the war, in the spring of 1991, Iraq submitted its first disclosure to UNSCOM. In it, Iraq declared that there were 6,394 mustard-filled 155mm artillery rounds stored at the Fallujah Proving Ground. (See Figure 3.) Iraq made no mention in this disclosure of the Ukhaydir Ammunition Storage Depot as a place where chemical rounds were deployed during the war.[11] Following this disclosure, according to published accounts, UNSCOM's chemical warfare inspection team inspected the Fallujah Proving Ground during its visit to Iraq between August 31 and September 9, 1991.[12]

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[7] Testimony of UNSCOM representatives before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, July 8, 1996.

[8] The United Nations Blue Book Series, Volume IX, "The United Nations and the Iraq-Kuwait Conflict 1990-1996," United Nations, Department of Public Information, New York, 1996, p. 5.

[9] The United Nations Blue Book Series, Volume IX, "The United Nations and the Iraq-Kuwait Conflict 1990-1996," United Nations, Department of Public Information, New York, 1996, p. 31 and 83.

[10] Testimony of UNSCOM representatives before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, July 29, 1997.

[11] Testimony of UNSCOM representatives before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, July 29, 1997.

[12] The United Nations Blue Book Series, Volume IX, "The United Nations and the Iraq-Kuwait Conflict 1990-1996," United Nations, Department of Public Information, New York, 1996, p. 353 and 357.

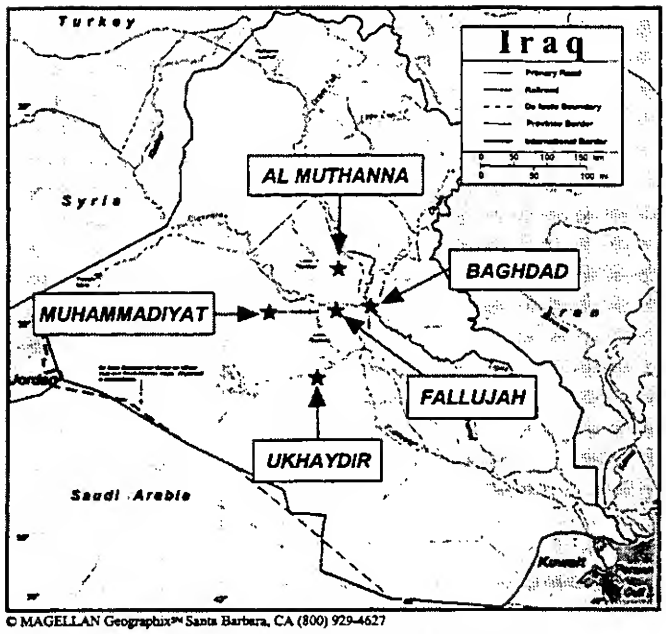

Figure 3. Fallujah, Al Muthanna, Muhammadiyat, and Ukhaydir in relation to Baghdad

3. UNSCOM's 1991 Fallujah Proving Ground Inspection

According to the United Nations Department of Public Information, UNSCOM inspectors visited the Fallujah Proving Ground in September 1991 to examine the mustard-filled rounds declared by Iraq.[13] Iraq declared then that it had moved the rounds to the Proving Ground in January 1991 from the Muthanna State Establishment located at Al Muthanna, Iraq's primary chemical production facility.[14,15] (See Figure 3.) Inspectors discovered 6,159 undamaged, grey-colored mustard-filled rounds at the Fallujah Proving Ground. UNSCOM also discovered 117 green-colored rounds. Of these 117, 10 were still filled with mustard. In addition, the inspectors found 104 grey or green fire and heat-damaged rounds, 10 of which still had agent in them. (See Figure 4.) When questioned, the Iraqis claimed the burned rounds were damaged at the Muthanna State Establishment.[16]

In total, during this inspection, UNSCOM accounted for 6,380 rounds, 14 fewer than acknowledged in Iraq's 1991 disclosure. (See Figure 5.) Ultimately, UNSCOM supervised the destruction of the 155mm rounds discovered at the Fallujah Proving Ground.[17]

Figure 4. Some of the damaged mustard-filled rounds at Fallujah Proving Ground

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[13] The United Nations Blue Book Series, Volume IX, "The United Nations and the Iraq-Kuwait Conflict 1990-1996," United Nations, Department of Public Information, New York, 1996, p. 357.

[14] Testimony of UNSCOM representatives before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, July 29, 1997.

[15] Testimony of UNSCOM representatives before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, July 8. 1996.

[16] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.

[17] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.

155mm Rounds At Fallujah (1991)

- *Total Declared*: 6,394
- *Total Discovered*:
  - 6,159 Undamaged Grey Rounds
  - + 117 Green Painted Rounds (107 Empty)
  - + 104 Burned Rounds (94 Empty)

6,380 Total Rounds Accounted For

Figure 5. 1991 UNSCOM accounting of 155mm mustard-filled rounds at Fallujah Proving Ground

4. Iraq's 1996 Disclosure

Iraq's second full, final, and complete disclosure did not discuss Fallujah Proving Ground or Ukhaydir. However, in the summer of 1996, responding to questions from UNSCOM, Iraq submitted a third disclosure of its chemical warfare capabilities. This disclosure contained additional information on the history of the production, filling, and deployment of 155mm mustard-filled rounds, including the fact that Iraq deployed 6,394 rounds to the Ukhaydir Ammunition Storage Depot in January 1991. Iraq had previously identified the Ukhaydir depot as a chemical storage area during the mid-1980s. However, Iraq did not identify Ukhaydir as a Gulf War chemical munitions storage site until the 1996 disclosure.[18]

5. UNSCOM's 1997 Ukhaydir Inspection

According to public testimony of UNSCOM representatives, UNSCOM inspectors visited the Ukhaydir Ammunition Storage Depot in April 1997, following the release of new information in Iraq's third disclosure.[19] During that visit, UNSCOM personnel inspected a bunker that was separated from the rest of the complex by a security fence. (See Figures 6 and 7.) According to Iraq's disclosures, this bunker, as well as others at the complex, had been used in the past for the storage of chemical weapons.[20] However, UNSCOM did not discover any mustard rounds inside the bunker.[21] According to Iraq, it stored no chemical rounds or other weapons in the bunkers during the Gulf War air campaign. Rather, Iraq claimed it stored the mustard-filled rounds in the open in various places around the depot during the Gulf War to protect them from

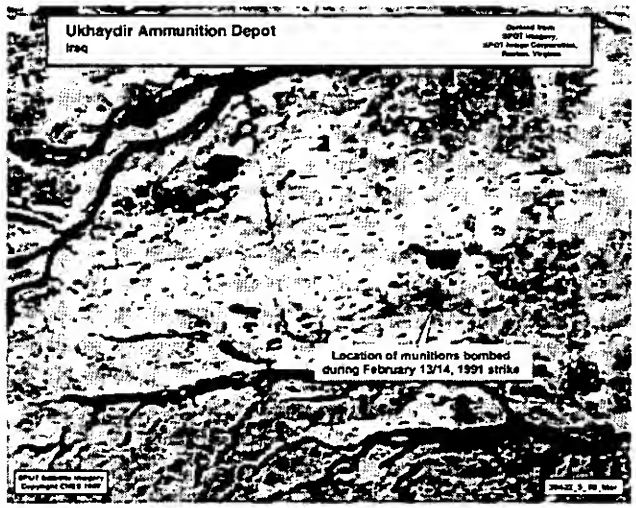

Figure 6. Image of Ukhaydir facility

[18] Testimony of UNSCOM representatives before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, July 29, 1997.

[19] Testimony of UNSCOM representatives before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, July 29, 1997.

[20] The United Nations Blue Book Series, Volume IX, "The United Nations and the Iraq-Kuwait Conflict 1990-1996," United Nations, Department of Public Information, New York, 1996, p. 450.

[21] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.

being damaged during Coalition bombings of storage bunkers.[22] According to an April 1996 UNSCOM release:

> Iraqi statements and documents show they went to great lengths to protect their chemical and biological munitions from aerial bombardment. Iraq stated that its biological agent-filled aerial bombs were deployed to three airfields and were placed in open pits away from bombing targets, covered with canvas and buried with dirt. Iraqi documents and UNSCOM inspections indicate that its chemical munitions were often hidden in the open in a similar fashion.[23]

During UNSCOM's inspection of the road in front of the bunker with the security fence, it noticed a repaired area that had obviously been hit by a bomb. The repaired area was still surrounded by rubble from the damaged section of the original roadway.[24] In examining the rubble, the inspectors discovered three intact 155mm rounds which, based on visual inspection, they assumed to be mustard-filled.[25] During a subsequent visit to Ukhaydir, later in 1997, UNSCOM inspectors discovered a fourth intact, mustard-filled 155mm round in the rubble around the repaired bomb crater.[26]

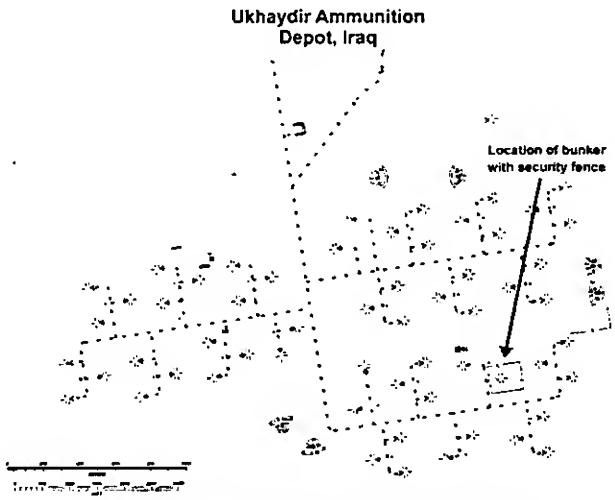

Figure 7. Schematic of Ukhaydir facility

6. UNSCOM Accounting as of Spring 1997

Although Iraq has never specifically stated that the mustard-filled rounds at Ukhaydir during the Gulf War were the same ones inspected by UNSCOM at the Fallujah Proving Ground in September 1991, this assumption is supported by the fact that Iraq declared the same number of rounds for both sites.[27] According to public testimony of UNSCOM representatives, UNSCOM

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[22] Testimony of UNSCOM representatives before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, July 29, 1997.

[23] Unclassified United Nations Special Commission on Iraq Release, April 26, 1996.

[24] Statement for the Record by Robert D Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, to the Presidential Advisory Committee on Gulf War Veterans' Illnesses, Subject: "Probable Release of Mustard Agent from the Ukhaydir Ammunition Storage Depot," July 29-30, 1997, p. 1 and 2.

[25] Testimony of UNSCOM representatives before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, July 29, 1997.

[26] Letter from Robert Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, February 17, 1999, Enclosure 2.

[27] Statement for the Record by Robert D Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, to the Presidential Advisory Committee on Gulf War

has determined that in January 1991, prior to the start of the air campaign, Iraq moved the rounds from the Muthanna State Establishment to the Ukhaydir Ammunition Storage Depot, closer to the anticipated area of operations.[28] The Intelligence Community assessed that the Iraqis moved the rounds from Ukhaydir to the Fallujah Proving Ground after the end of the war: "[T]he rounds located at Fallujah arrived there about the same time that the stacks at Ukhaydir ... departed."[29] By spring 1997, UNSCOM had assessed that the rounds were the same and was able to account for 6,384 of the 6,394 declared by Iraq; most of these (6,380) were inspected at the Fallujah Proving Ground in September 1991, while an additional four were discovered during the two separate inspections at Ukhaydir in the spring of 1997. (See Figure 8.)

155mm Rounds at Fallujah and Ukhaydir

- *Total Declared (1991 and 1996)*: 6,394
- *Total Discovered (1991)*:
  - 6,159 Undamaged Grey Rounds
  - + 117 Green Painted Rounds (107 Leaked)
  - + 104 Burned Rounds (94 Leaked)
  - *6,380 Total Rounds Accounted For*
- *Total Discovered (1997)*:
  - 6,380 Rounds Discovered in 1991
  - + 4 Rounds at Ukhaydir
  - *6,384 Total Rounds Accounted For*

Figure 8. 1997 UNSCOM accounting of 155mm mustard-filled rounds at Fallujah and Ukhaydir

C. 1997 Damage Assessment of Airstrikes

Once it was assessed that the mustard-filled rounds inspected at the Fallujah Proving Ground in 1991 were at Ukhaydir during the Gulf War, the Intelligence Community concluded that the damage discovered at the Fallujah Proving Ground may have occurred while the rounds were at Ukhaydir.[30] In 1997, after UNSCOM's first Ukhaydir inspection, but before its second, the Intelligence Community examined the available information to determine how the rounds became empty and when the damage could have taken place and whether any mustard agent that may have been released reached US forces located in Saudi Arabia. After an extensive investigation, which included a review of imagery from the Gulf War, the Intelligence Community determined that the Iraqis stacked the mustard-filled rounds in the open in several areas throughout the Ukhaydir Ammunition Storage Depot. They placed one large stack directly

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Veterans' Illnesses, Subject: "Probable Release of Mustard Agent from the Ukhaydir Ammunition Storage Depot," July 29-30, 1997, p. 2.

[28] Testimony of UNSCOM representatives before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, July 29, 1997.

[29] Statement for the Record by Robert D Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, to the Presidential Advisory Committee on Gulf War Veterans' Illnesses, Subject: "Probable Release of Mustard Agent from the Ukhaydir Ammunition Storage Depot," July 29-30, 1997, p. 2.

[30] Statement for the Record by Robert D Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, to the Presidential Advisory Committee on Gulf War Veterans' Illnesses, Subject: "Probable Release of Mustard Agent from the Ukhaydir Ammunition Storage Depot," July 29-30, 1997, p. 2.

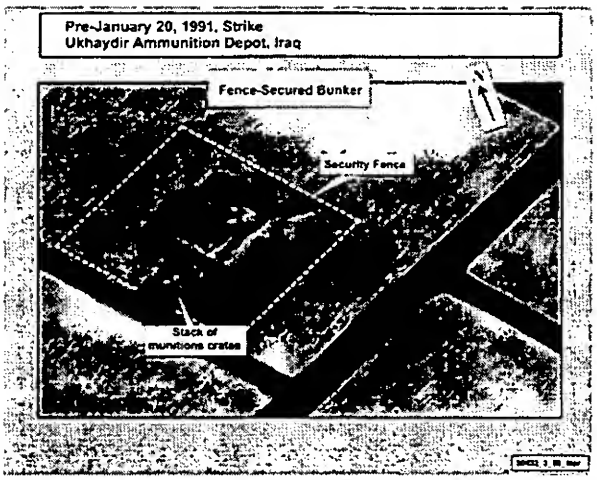

Figure 9. 155mm mustard-filled rounds in front of bunker at Ukhaydir

in front of the fenced bunker later inspected by UNSCOM. (See Figure 9.[31]) The Intelligence Community believes the damaged and empty munitions inspected at the Fallujah Proving Ground were in this stack. As the Intelligence Community noted, "other similar stacks were located in the open at various locations in the depot, but no other stacks were damaged."[32] The Intelligence Community also assessed in 1997 that it was possible no rounds were damaged at Ukhaydir during the Gulf War, but since some rounds were damaged at some time, the damage could have occurred during two separate coalition airstrikes on Ukhaydir, the first on January 20, 1991, and the second on the night of February 13/14, 1991.[33,34]

1. January 20, 1991

On the night of January 20, 1991, Coalition forces bombed the fenced bunker, starting a large fire indicated by a massive soot and debris footprint. (See Figure 10.) In 1997, the Intelligence Community assessed that this fire could have damaged the 104 burned rounds discovered at the Fallujah Proving Ground. At some point after the fire, Iraq moved the rounds beyond the security fence to the road paralleling the front of the bunker, separating them into two stacks along the road.[35] (See Figure 11.)

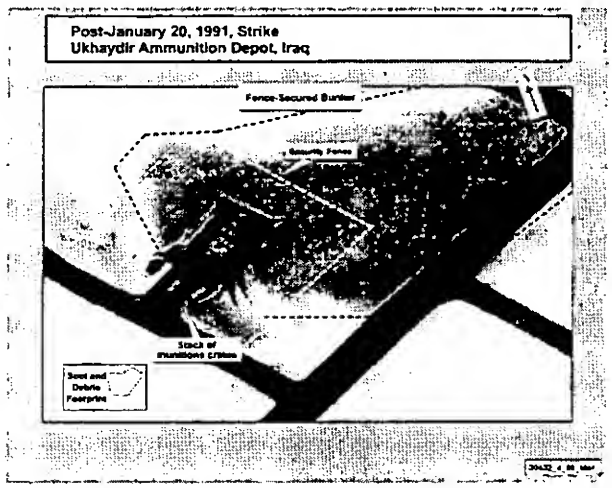

Figure 10. Extensive area of debris from bombing of the bunker

[31] Figures 9 through 12 are releasable drawings derived from classified documents.

[32] Statement for the Record by Robert D Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, to the Presidential Advisory Committee on Gulf War Veterans' Illnesses, Subject: "Probable Release of Mustard Agent from the Ukhaydir Ammunition Storage Depot," July 29-30, 1997, p. 1 and 2.

[33] This air strike occurred just before midnight on the night of February 13, 1991, or very early in the morning on February 14, 1991. Therefore, this air strike and the subsequent damage will be referred to as occurring on February 13/14, 1991, throughout this narrative.

[34] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.

[35] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.

2. February 13/14, 1991

In 1997, the Intelligence Community also assessed that around midnight on the night of February 13, 1991, a Coalition bomb hit, or disturbed, the stack on the left in Figure 11 during another airstrike on the facility.[36] (See Figure 12.) The Intelligence Community assumed the bomb punched through the stack, possibly destroying some rounds but causing little or no burn damage to the rounds in the stack. The bomb then exploded underground, creating a crater under the stack, causing approximately 560 mustard-filled rounds to fall, possibly damaging some and causing their agent to leak.[37]

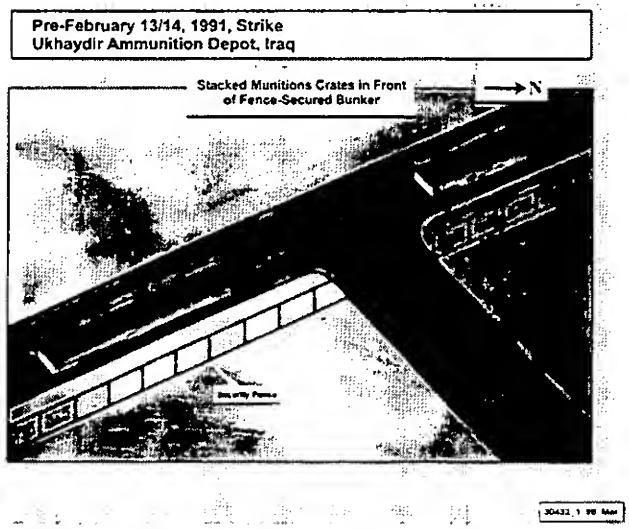

Figure 11. Stacks of 155mm mustard-filled rounds on the road in front of the bunker

D. Modeling Efforts

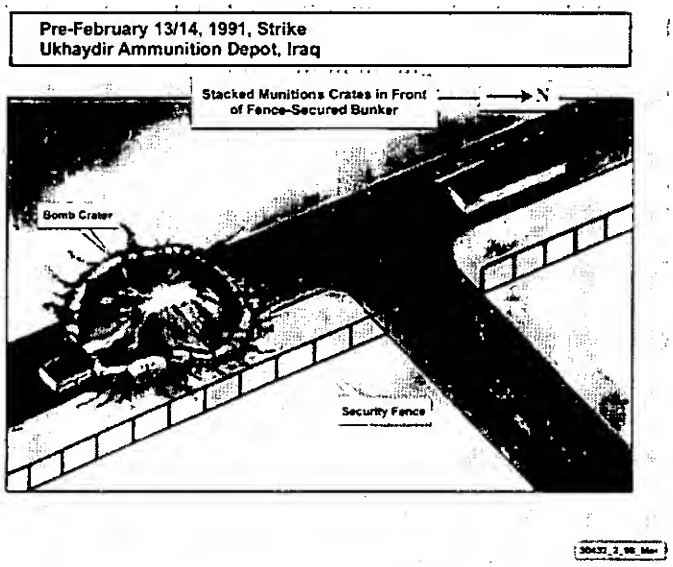

Figure 12. Stack of 155mm mustard-filled rounds after airstrike

After the Intelligence Community assessed that it was possible that mustard agent could have been released from Ukhaydir during the air campaign, in 1997, the Office of the Special Assistant and the CIA modeled the potential extent of any resulting hazard areas to see if the possible mustard agent releases could have reached US troops.

The CIA and DoD conducted separate modeling efforts. The CIA conducted preliminary modeling in the spring of 1997 for presentation at the September 1997 meeting of the Presidential Advisory Committee on Gulf War Veterans' Illnesses in Washington, DC. The modeling presented to the Committee was preliminary because it used incomplete weather data and only one model to produce the hazard area.[38] In late 1997, DoD conducted a more

[36] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.

[37] Testimony of Robert D Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, September 4, 1997.

detailed, follow-on modeling of the potential mustard releases at Ukhaydir. This effort used several models and incorporated more comprehensive weather data.

The CIA developed the source characteristics[39] for both its own and DoD's modeling in the spring of 1997 based on UNSCOM's discoveries at both the Fallujah Proving Ground in 1991 and Ukhaydir in 1997. The modelers always chose the more conservative path, that is, they always assumed the highest possible amount of agent was released, consistent with UNSCOM discoveries up to that point.

1. CIA's Analysis of January 20, 1991, Storage Bunker Fire

In 1997, when it developed the source characteristics for the potential release on January 20th, the CIA assessed that the bunker fire started by the Coalition airstrike could have caused 94 mustard-filled 155mm rounds to release their agent.[40] However, an examination of the soot deposit indicated that the fire was quite extensive. Therefore, most of the mustard probably burned immediately, releasing very little agent into the atmosphere.[41]

Extensive weather data was not available when the CIA conducted its preliminary modeling, so it used an analysis of the direction of the bunker's soot pattern, which suggested that the "initial wind direction [was] to the southeast."[42] This meant the wind was blowing parallel to the Saudi border and parallel to the US forces located there. According to CIA testimony before the Presidential Advisory Committee:

> Using this initial wind direction, we have modeled the potential release from the 94 rounds that did not contain agent when inspected. The concentration of mustard agent that likely survived the blast and fire would probably *not* [*emphasis added*] have been above the general population limit [see glossary for definition] beyond about 40 [kilometers]. Even if the meteorological data change the wind direction, the plume [hazard area] will disperse hundreds of kilometers away from our troops.[43]

Due to the absence of extensive meteorological data, the CIA did not produce a representation of the simulated hazard area showing the extent of any potential exposures.[44] However, on January

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[38] Testimony of Robert D Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, September 4, 1997.
[39] Source characteristics discuss how much chemical agent may have been released, how it may have been released, and at what rate it was released.
[40] Testimony of Robert D Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, September 4, 1997.
[41] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.
[42] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.
[43] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.
[44] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.

20th, US forces were located south of the Saudi border, over 300 kilometers from Ukhaydir and far beyond the 40 kilometer radius shown in Figure 13. Because CIA's modeling showed such a small potential hazard area,[45] DoD did not model this strike.

2. CIA's Analysis of February 13/14, 1991, Strike of Munitions Stored on the Road

The CIA developed source characteristics for the February 13/14, 1991, strike in the spring of 1997 from UNSCOM inspection data before UNSCOM discovered the fourth round at Ukhaydir. After their first inspection of Ukhaydir, UNSCOM had accounted for all but 11 of the 6,394 mustard-filled 155mm rounds declared by Iraq (6,380 at the Fallujah Proving Ground plus 3 at Ukhaydir). The CIA assumed that the direct impact on the 11 rounds caused them to burst and aerosolize 70 percent of their contents (seven gallons of mustard agent).[46]

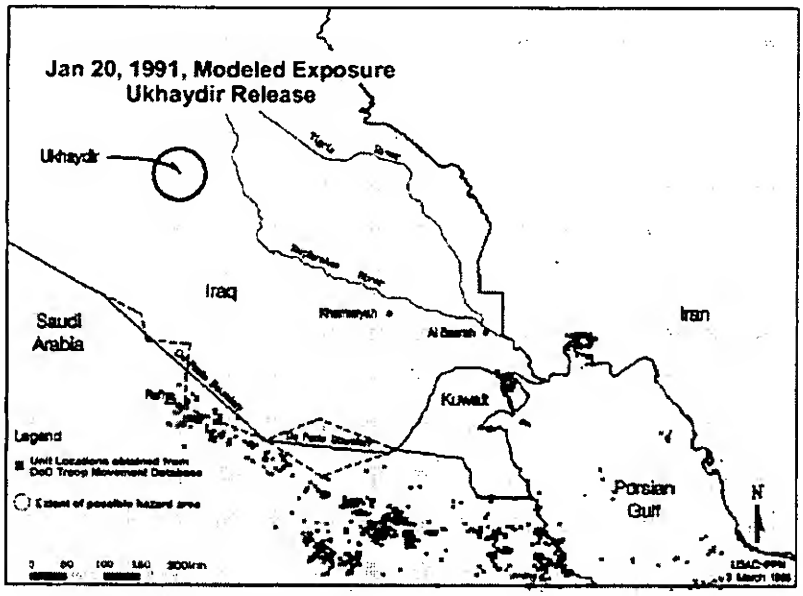

Figure 13. Map showing 40 kilometer radius around Ukhaydir and the locations of US forces on January 20, 1991

In addition to the 11 rounds potentially destroyed by the impact, the CIA determined that as many as 560 rounds fell into the crater after the bomb exploded underground. According to the CIA, "on the basis of US drop tests from a height of 7 feet, approximately 1 in 40 rounds that dropped into the bomb crater would have leaked, or only 14 of the total 560." Additional US drop tests from a height of 40 feet would "increase the ratio to 1 in 8 leaking, or 70 of the 560."[47] Although these tests showed that fewer than 107 rounds would have leaked after falling into the bomb crater, the CIA followed the more conservative path and assumed all 107 of the empty, green rounds inspected at the Fallujah Proving Ground leaked, releasing approximately 83 gallons of mustard agent. After adding the seven gallons from the 11 rounds, the CIA assumed a total of 90 gallons of mustard agent was released as a result of the February strike.[48]

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[45] See Tab E for information on how to read the hazard area maps in this narrative.
[46] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.
[47] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.
[48] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.

The CIA presented its preliminary modeling results for the February strike at a hearing of the Presidential Advisory Committee on Gulf War Veterans' Illnesses on September 4, 1997. Given the source characteristics and the weather conditions at the time of the release, the CIA's modeling produced a hazard area of contamination above the general population limit extending approximately 125 kilometers toward the southwest. The modeling showed the hazard area's maximum width would have been between 10 and 20 kilometers.[49] (See Figure 14.)

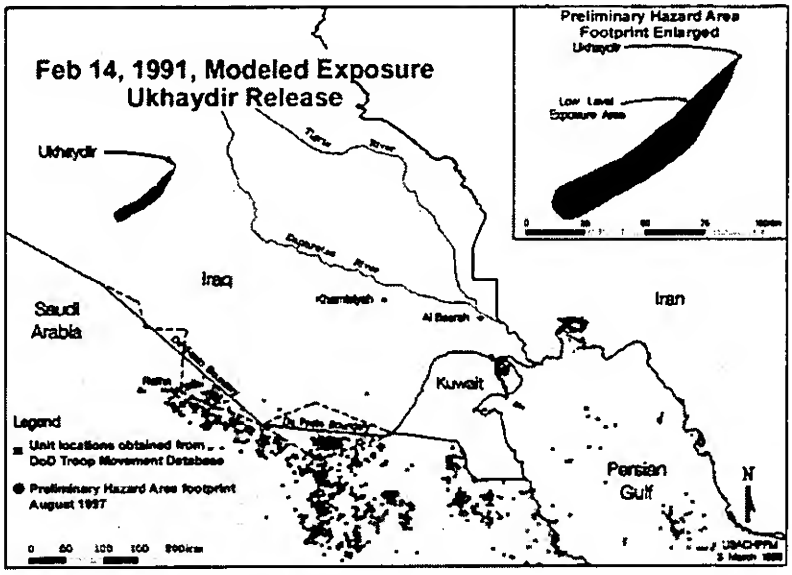

Figure 14. CIA's preliminary modeling results for the February airstrike

3. DoD's Analysis of February 13/14, 1991, Strike of Munitions Stored on the Road

a. DoD's Modeling Methodology

The DoD also modeled the February strike, but employed more detailed weather information and additional models than the CIA's preliminary modeling.

DoD used two types of models to determine the extent of the hazard created by the possible mustard agent release: weather prediction models and transport/diffusion models. Weather prediction models reconstruct the weather conditions in an area of potential release. Transport/diffusion models use the source characterization and data (e.g., wind and temperature) generated by weather prediction models to simulate how an agent released into the atmosphere might disperse, and to define the extent of any subsequent contamination. Using a union of the results from several independent weather and dispersion models develops an "ensemble" potential hazard area. This ensemble approach provides an array of "credible predicted concentrations for use in determining the area where service personnel might have been exposed"[50] and increases the confidence in the resulting hazard area. More information about DoD's modeling is provided in Tab D.

[49] Persian Gulf War Illnesses Task Force, "Update on Potential Mustard Agent Release at Ukhaydir Ammunition Storage Depot," September 4, 1997.

[50] Anthes, Richard, Steve Hanna, Bruce Hicks, and Will Pendergrass, Subject: "Comments by Peer Review Panel on Khamisiyah Modeling Report and Presentations on November 4-5, 1997," December 11, 1997, p. 7.

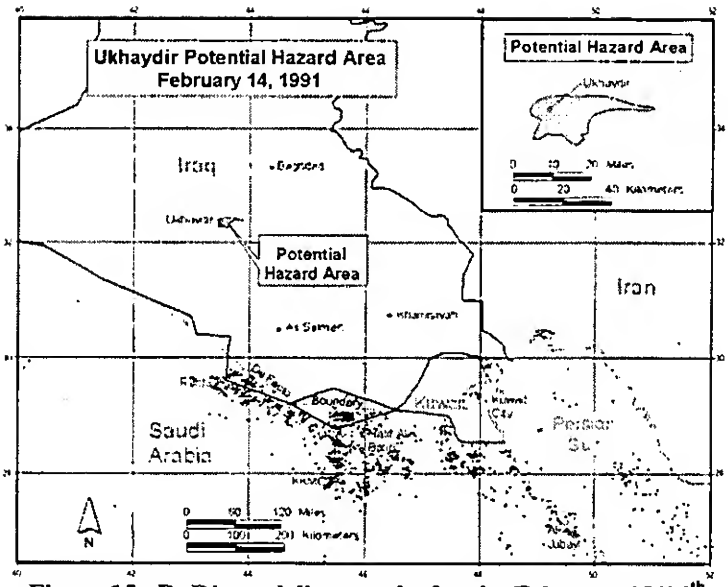

Figure 15. DoD's modeling results for the February 13/14th airstrike, Day 1

b. DoD's Modeling Results

During the first 24 hours—when the rounds would have released the most agent, the weather models predicted low-level winds out of the north/northwest, producing a southerly to southeasterly hazard area. The hazard area extended the farthest from Ukhaydir and closest to US troop locations during this initial 24-hour period. Nevertheless, the hazard area was still 275 kilometers from US units at its closest point. (See Figure 15.[51])

On the second day, the winds were initially from the west and then generally calm in the vicinity of Ukhaydir, with wide shifts in direction from north/northeast to south/southwest. Overall, the winds were lighter than on the first day. The calm weather, combined with a significantly reduced rate of agent evaporation, produced a hazard area emanating from the crater and directed to the east. The hazard area for the second day did not extend as far south as that for the first day, so it also did not reach US troop locations. (See Figure 16.)

Lower evaporation rates from the crater and calm winds slowed dispersion further on the third day. That day's winds were out of the southeast and pushed the hazard area approximately 20 kilometers to the northwest, away from US troops. (See Figure 17.)

After the third day, the models predicted that the level of mustard agent did not exceed the general population limit anywhere, and therefore no longer presented a threat to US troops. DoD completed this modeling of the February airstrike in early 1998. All the modeled hazard areas fell hundreds of kilometers short

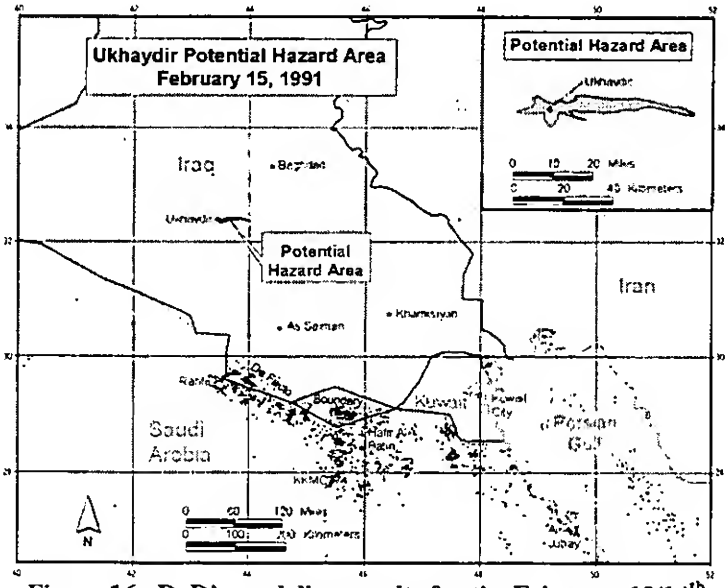

Figure 16. DoD's modeling results for the February 13/14th airstrike, Day 2

[51] See Tab G for a comparison of the preliminary and follow-on hazard areas for Day 1.

of reaching US troops.

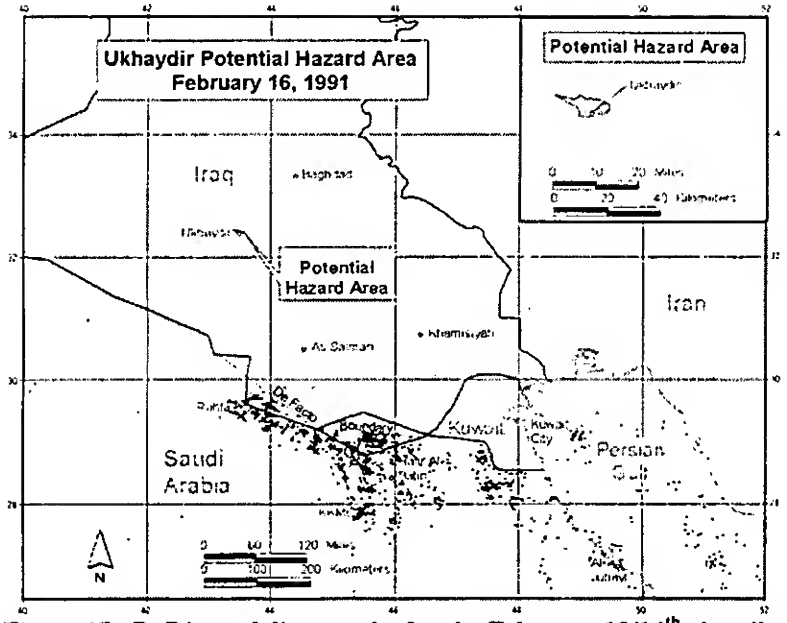

Figure 17. DoD's modeling results for the February 13/14th airstrike, Day 3

E. UNSCOM's 1998 Ukhaydir Inspection

While the DoD modeling progressed, UNSCOM continued its work in Iraq. In the spring of 1998, Iraq told UNSCOM that it had unilaterally excavated the area around the bomb crater at Ukhaydir and discovered 12 additional mustard-filled 155mm rounds. Consequently, in the summer of 1998, UNSCOM inspectors returned to Ukhaydir to ensure the site was cleared of chemical weapons, investigate Iraq's excavation and perform a geophysical survey of the area around the bomb crater using ground-penetrating radar.[52]

According to Iraq, it found five of the rounds under the repaired crater in the roadway in front of the bunker. Iraq also claimed that the remaining seven rounds were found in the area around the roadway, near where UNSCOM had discovered the four intact mustard-filled rounds in 1997. Like those rounds, the 12 rounds excavated by Iraq were intact and painted grey, with no sign of burn damage. The inspectors examined the contents of two of the twelve rounds and found them consistent with mustard. The other shells were examined and all were found to contain liquid. UNSCOM transported all the rounds it found during these inspections of the Ukhaydir Ammunition Storage Depot to the Muthanna State Establishment where they were destroyed under UNSCOM supervision.[53]

During its geophysical survey, UNSCOM used ground-penetrating radar to search an area around the repaired bomb crater in the road. They did not discover any additional intact munitions during this survey. Moreover, inspectors found no evidence of significant munitions debris or other evidence of chemical munitions destruction at the site. The only metal inspectors found in the survey was a piece of angle iron. They detected no mustard contamination in the area they

[52] Letter from Robert Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, February 17, 1999, Enclosure 2.
[53] Letter from Robert Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, February 17, 1999, Enclosure 2.

surveyed. Iraq continues to state that no chemical rounds were destroyed at Ukhaydir during the Gulf War.[54]

F. CIA's Reassessments

Although both DoD's and CIA's modeling showed that it was unlikely any mustard agent reached US forces in Saudi Arabia, the new information obtained from UNSCOM's 1998 inspection caused CIA to re-evaluate its original assessment of a likely release from Ukhaydir during the Gulf War.

1. February 1999 Letter

After UNSCOM returned from its 1998 inspection of Ukhaydir, the CIA re-evaluated its assessment of whether the airstrikes on January 20, 1991, and February 13/14, 1991, caused any releases of mustard agent at Ukhaydir. In February 1999, the CIA's Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues sent a letter to DoD's Special Assistant for Gulf War Illnesses providing the CIA's revised assessment. Both the CIA and UNSCOM continue to assess that the rounds inspected at the Fallujah Proving Ground in 1991 were at Ukhaydir during the air campaign. However, the CIA stated in its letter that it now believes a release from Ukhaydir as a result of either airstrike is unlikely.

For the January 20, 1991, bunker fire and the burned rounds at the Fallujah Proving Ground, the CIA stated, "There was no direct evidence the bunker fire actually burned any rounds. [Therefore, it] is no longer considered to be a case for a release."[55] The CIA's letter did discuss a trailer fire at an unknown time about 20 miles away from Ukhaydir as an alternate explanation for the burn damage discovered at the Fallujah Proving Ground.[56]

For the February airstrike and the missing and empty rounds from the Fallujah Proving Ground, the CIA stated that "Damage to the 11 rounds from direct impact of the bomb against the stack is now considered to be unlikely ... [and] it is ... unlikely that the empty green rounds—107 in all—modeled previously are involved in the Coalition bombing." This assessment was based on these facts:

> [N]o metal fragments from damaged rounds were found ... and no chemical contamination was identified .... Also, as shown in [Figure 12] the center of the crater was just to the side of the stack ... indicating the bomb did not fly over the stack but landed just in front of the stack .... Finally, the 11 round figure was also based on 11 missing rounds; since that time, Iraq [has] found an additional 12 rounds—more than enough to compensate for the missing rounds.

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[54] Letter from Robert Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, February 17, 1999, Enclosure 2.

[55] Letter from Robert Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, February 17, 1999, Enclosure 2.

[56] Letter from Robert Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, February 17, 1999, Enclosure 2.

> ... [Also,] ninety-eight percent of the 6,395 rounds found ... were gray in color, including all 16 rounds found [at Ukhaydir]. We do not know why the green-colored rounds were empty. UNSCOM found no evidence of leakage or damage when they were inspected in 1991—unusual if the rounds were truly damaged in a fall into the crater.
>
> ... [For the 107 empty green rounds,] it is unlikely that the rounds were damaged when they fell into the crater given the absence of leaking rounds in 1991, contamination and shell fragments near the road in 1998, or leaking or damage to the 16 rounds found [at Ukhaydir] in 1997 and 1998 .... In addition, we assess—because of the separation of the stack and the crater—that the rounds more likely slid into the crater or fell a short distance onto soft earth as opposed to having a long damaging fall.
>
> ... [Finally,] the Iraqis indicated that no rounds were damaged at Ukhaydir even though they had motivation to falsely declare damaged rounds there.[57]

2. October 1999 Letter

In October, 1999, the CIA's Special Assistant for Persian Gulf War Illnesses Issues sent a second letter to DoD's Special Assistant for Gulf War Illnesses, again discussing possible explanations for the damage discovered at the Fallujah Proving Ground in 1991.

Although the letter stated that an "[i]ntense fire [would be] required to burst [the] rounds," it did not mention the January 20, 1991, bunker fire at Ukhaydir. The letter stated that the CIA now believes the burned rounds inspected at the Fallujah Proving Ground in 1991 definitely released their agent and discussed five possible locations and times for this release:

- somewhere on the roadways from Al Muthanna to Ukhaydir, some time between January 10 and 15, 1991;
- somewhere in Iraq, some time prior to 1989, during the Iran-Iraq War;
- at Ukhaydir some time between March and September 1991;
- at Al Muthanna some time between November 1990 and January 1991, before the Gulf War air campaign; and
- at the trailer fire located within 20 kilometers of Ukhaydir discussed in the February letter, some time between March 10 and 31, 1991.[58]

The CIA based these possible locations and times on "various declarations to UNSCOM [the first, fourth, and fifth locations] and informed speculation [the second and third locations]. [The second and third locations are] based on the fact that, along with the burned rounds [at the

[57] Letter from Robert Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, February 17, 1999, Enclosure 2.

[58] Letter from Robert Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, October 14, 1999.

Fallujah Proving Ground,] the inspectors found completely dry obsolete green rounds[,] indicating that Iraq may have cleaned ... old rounds out of Ukhaydir, a C[hemical] W[eapons] site since the mid-80's."[59]

This second letter characterized the February strike as an "unlikely release, based on [the] lack of evidence of damage seen during [the] 1998 UNSCOM inspection." The letter did not specifically address how the empty, green rounds from UNSCOM's inspection at the Fallujah Proving Ground might have leaked.[60]

G. Lessons Learned

Because this narrative does not review the training, techniques, or procedures used by Coalition forces during the Gulf War, there are no doctrinal lessons to be learned from events at Ukhaydir. Ukhaydir was a legitimate target of the Coalition air campaign. As such, it was struck on several occasions. It is an unfortunate fact of war that aerial bombs, through no fault of the operator, occasionally miss their intended targets, in this case the bunkers believed to store chemical weapons. This review of events at Ukhaydir provided no insight into improving the manner in which the US military conducts war.

IV. ASSESSMENT

For the January 20, 1991, bunker fire, we have contradictory information. Although the CIA believes the burn-damaged rounds inspected at the Fallujah Proving Ground were not damaged at Ukhaydir, they were likely at Ukhaydir during the bunker fire and an intense fire would have been required to cause the damage seen in those rounds. Although we have no direct evidence the bunker fire actually burned the rounds, we cannot eliminate it as a possibility. Therefore, our assessment of the possibility of a release on that day is indeterminate. However, even if a release occurred, the CIA modeling conducted in 1997 showed that very little mustard agent would have survived the fire and what was released would not have exceeded the general population limit beyond a 40 kilometer radius from Ukhaydir, well away from US troops located over 300 kilometers away along the Saudi Arabian border. Therefore, we assess it as unlikely that any US forces were exposed to mustard agent from the airstrike on January 20, 1991.

For the February 13/14, 1991, strike on the road, we also have contradictory information. Again, the rounds inspected at the Fallujah Proving Ground were likely at Ukhaydir during this airstrike and a stack of rounds was on the road when it was hit. Furthermore, based on the location of the crater, we know that if the Coalition bomb did not land on the stack of munitions, it landed very close to it, possibly destroying some of them. The source terms for both the CIA and DoD 1997 modeling of the strike on the road conservatively assumed a release from both the rounds

[59] Letter from Robert Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, October 14, 1999.
[60] Letter from Robert Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, Central Intelligence Agency, October 14, 1999.

UNSCOM had not accounted for at the time of the modeling and the 107 empty green rounds inspected at the Fallujah Proving Ground.

During its 1998 inspection of Ukhaydir, UNSCOM inspected 12 rounds unilaterally excavated by Iraq. Although this would appear to account for the missing rounds, Ukhaydir was not under UNSCOM control in the periods between inspections and Iraq excavated the rounds without UNSCOM supervision. Iraq also claimed to have found the rounds in an area previously inspected by UNSCOM. We cannot say Iraq placed the "discovered" rounds there between UNSCOM's 1997 and 1998 inspections, but we cannot categorically say Iraq did not. The CIA also based its revised assessment of a release on February 13/14th on the lack of munitions debris discovered by UNSCOM in 1998. However, because Ukhaydir was not under UNSCOM control between inspections, Iraq could have cleared the area of debris between 1997 and 1998.

The CIA also revised its assessment of whether the empty green rounds leaked after falling into the crater in the road because of the same lack of debris and because only 117 of all the rounds inspected were green. However, these rounds, like the others at the Fallujah Proving Ground, were likely at Ukhaydir during this strike. We have no way of determining the color of the rounds in the stack. It is at least possible these rounds were among those that fell into the crater. The CIA also speculated that it was possible the empty green rounds were empty because they had never been filled with agent. However, of the green rounds inspected, 10 were filled with agent. We have no way of knowing if those that were empty when inspected were previously filled with agent.

Without additional information to resolve these contradictions, we cannot determine if the February strike caused the release of any mustard agent. Therefore, until more conclusive information becomes available, our assessment of whether a mustard release occurred is indeterminate. However, even if a mustard release occurred, both CIA and DoD's 1997 modeling, using a very conservative estimate of the amount of chemical warfare agent possibly released, showed that the hazard areas would have been well away from the known locations of US forces over 300 kilometers away along the Saudi Arabian border. For this reason, our assessment of the likelihood of exposure as a result of any release at Ukhaydir is unlikely.

This case is still being investigated. As additional information becomes available it will be incorporated. If you have records, photographs, recollections, or find errors in the details reported, please contact my office at 1-800-497-6261.

TAB A – Acronyms, Abbreviations, and Glossary

This provides a listing of acronyms found in this report. Additionally, the glossary section provides definitions for selected technical terms that are not found in common usage.

Acronyms and Abbreviations

CIA ..... Central Intelligence Agency
COAMPS ..... Coupled Ocean-Atmosphere Mesoscale Prediction System
CW ..... chemical warfare
DCI ..... Director of Central Intelligence
DoD ..... Department of Defense
GDAS ..... Global Data Assimilation System
GPL ..... general population limit
HPAC ..... Hazard Prediction Assessment Capability
NBC ..... nuclear, biological, and chemical
NOGAPS ..... Naval Operational Global Atmospheric Prediction System
OMEGA ..... Operational Multiscale Environment Model with Grid Adaptivity
SCIPUFF ..... Second-order Closure Integrated Puff
UNSCOM ..... United Nations Special Commission on Iraq
US ..... United States
VLSTRACK ..... Vapor, Liquid, and Solid Tracking

Glossary

Chemical warfare agent — A chemical warfare agent is a chemical substance excluding riot control agents, herbicides, smoke, and flame, used in military operations to kill, seriously injure, or incapacitate though its physiological effects. Chemical warfare agents include blood, nerve, blister, choking, and incapacitating agents.[61]

General population limit — The general population limit is the average concentration below which the general population, including children and the elderly, could remain indefinitely with no effects. For example, the general population limit for mustard is 0.432 milligram-minute per cubic meter of air (0.0001 x 72 hours x 60 minutes).[62]

GulfLINK — GulfLINK is a World Wide Web site maintained by the Office of the Assistant to the Deputy Secretary of Defense for Gulf War Illnesses (www.gulflink.osd.mil).

Intelligence Community — The Intelligence Community is the Central Intelligence Agency, the Defense Intelligence Agency, the Bureau of Intelligence and Research (State Department), the National Security Agency, the National Imagery and Mapping Agency, the military services' intelligence staffs and centers, and other organizations within the Departments of Defense, Treasury, Justice, and Energy. Intelligence related to military efforts includes information at the strategic, operational, and tactical levels.

Mustard agent — A group of blister agents that include sulfur mustards (H and HD) and nitrogen mustards (HN-1, HN-2, HN-3), which are considered derivatives of ammonia. Mustard agent can penetrate skin and many materials. Mustard agents are very persistent under cold and temperate conditions.[63]

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[61] US Army Field Manual 8-285; US Navy Medical Publication P-5041, US Air Force Joint Manual 44-149, US Marine Corps Fleet Marine Force Manual 11-11, "Treatment of Chemical Agent Casualties and Conventional Military Chemical Injuries, Glossary, Section II, Definitions and Terms," December 22, 1995.

[62] US Army Pamphlet 40-173, "Occupational Health Guidelines for the Evaluation and Control of Occupational Exposure to Mustard Agents H, HD, and HT," August 30, 1991.

[63] US Army Field Manual 3-9, US Navy Publication P-467, US Air Force Manual 355-7, "Potential Military Chemical/Biological Agents and Compounds," December 12, 1990, p. 30.

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Testimony of Robert D Walpole, Special Assistant to the Director of Central Intelligence for Persian Gulf War Illnesses Issues, before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, September 4, 1997.

Testimony of UNSCOM representatives before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, July 8, 1996.

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US Army Field Manual 8-285, US Navy Medical Publication P-5041, US Air Force Joint Manual 44-149, US Marine Corps Fleet Marine Force Manual 11-11, "Treatment of Chemical Agent Casualties and Conventional Military Chemical Injuries, Glossary, Section II, Definitions and Terms," December 22, 1995.

US Army Pamphlet 40-173, "Occupational Health Guidelines for the Evaluation and Control of Occupational Exposure to Mustard Agents H, HD, and HT," August 30, 1991.

TAB C – Methodology For Chemical Incident Investigation

The Department of Defense requires a common framework for our investigations and assessments of chemical warfare agent reports, so we turned to the United Nations and the international community, which had chemical weapons experience (e.g., the United Nations' investigation of the chemical weapons used during the 1980-88 Iran-Iraq war). Because the modern battlefield is complex, the international community developed investigation and validation protocols[64] to provide objective procedures for possible chemical weapons incidents. The methodology we are using is based on these international protocols and guidelines. The methodology includes:

- A detailed written record of the conditions at the site;
- Physical evidence from the site such as weapons fragments, soil, water, vegetation, or human or animal tissue samples;
- A record of the chain of custody during transportation of the evidence;
- The testimony of witnesses;
- Multiple analyses; and
- A review of the evidence by an expert panel.

While the methodology used to investigate chemical incidents (Figure 18) is based on these protocols, the passage of time since the Gulf War makes it difficult to obtain certain types of documentary evidence, and physical evidence often was not collected at the time of an event. Therefore, we cannot apply a rigid template to all incidents, and each investigation must be tailored to its unique circumstances. Accordingly, we designed our methodology to provide a thorough, investigative process to define the circumstances of each incident and determine what happened. The major efforts in our methodology are:

- To substantiate the incident;
- To document available medical reports related to the incident;

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[64] "Convention on the Prohibition of the Development, Production, Stockpiling, and Use of Chemical Weapons and on Their Destruction," April 29, 1997. This chemical weapons convention was opened for signature in Paris, France, on January 13, 1993. It has been signed by 165 states and ratified or acceded to by 106 states as of February 1998. It was signed by the United States on January 13, 1993, and ratified on April 25, 1997. Part XI of the convention, "Investigations in Cases of Alleged Use of Chemical Weapons," details some of the procedures. Other protocols and guidelines were found in Methodology and Instrumentation for Sampling and Analysis in the Verification of Chemical Disarmament, The Ministry for Foreign Affairs of Finland, Helsinki, Finland, 1985; Verification Methods, Handling, and Assessment Of Unusual Events In Relation To Allegations of the Use of Novel Chemical Warfare Agents, Consultant University of Saskatchewan in conjunction with the Verification Research Unit of External Affairs and International Trade Canada, March 1990; and Handbook for the Investigation of Allegations of the Use of Chemical or Biological Weapons, Department of External Affairs, Department of National Defence, Health and Welfare Canada, and Agriculture Canada, November 1985. US Army Field Manual 3-4, US Marine Corps Fleet Marine Force Manual 11-9, "NBC Protection," May 1992; US Army Field Manual 8-285, US Navy NAVMED P-5041, US Air Force Manual 44-149, US Marine Corps Fleet Marine Force Manual 11-11 (adopted as NATO Field Manual 8-285), "Treatment Of Chemical Agent Casualties and Conventional Military Chemical Injuries," December 22, 1995; US Army Field Manual 19-20, "Law Enforcement Investigations," November 25, 1985; and other DoD investigational procedures contributed ideas for developing this methodology.

- To interview appropriate people;
- To obtain information available to external organizations; and
- To assess the results.

A case usually starts with a report of a possible chemical warfare agent incident, often from a veteran. To substantiate the circumstances surrounding an incident, the investigator searches for documentation from operational, intelligence, and environmental logs. This focuses the investigation on a specific time, date, and location, clarifies the conditions under which the incident occurred, and determines whether there is "hard," as well as anecdotal, evidence.

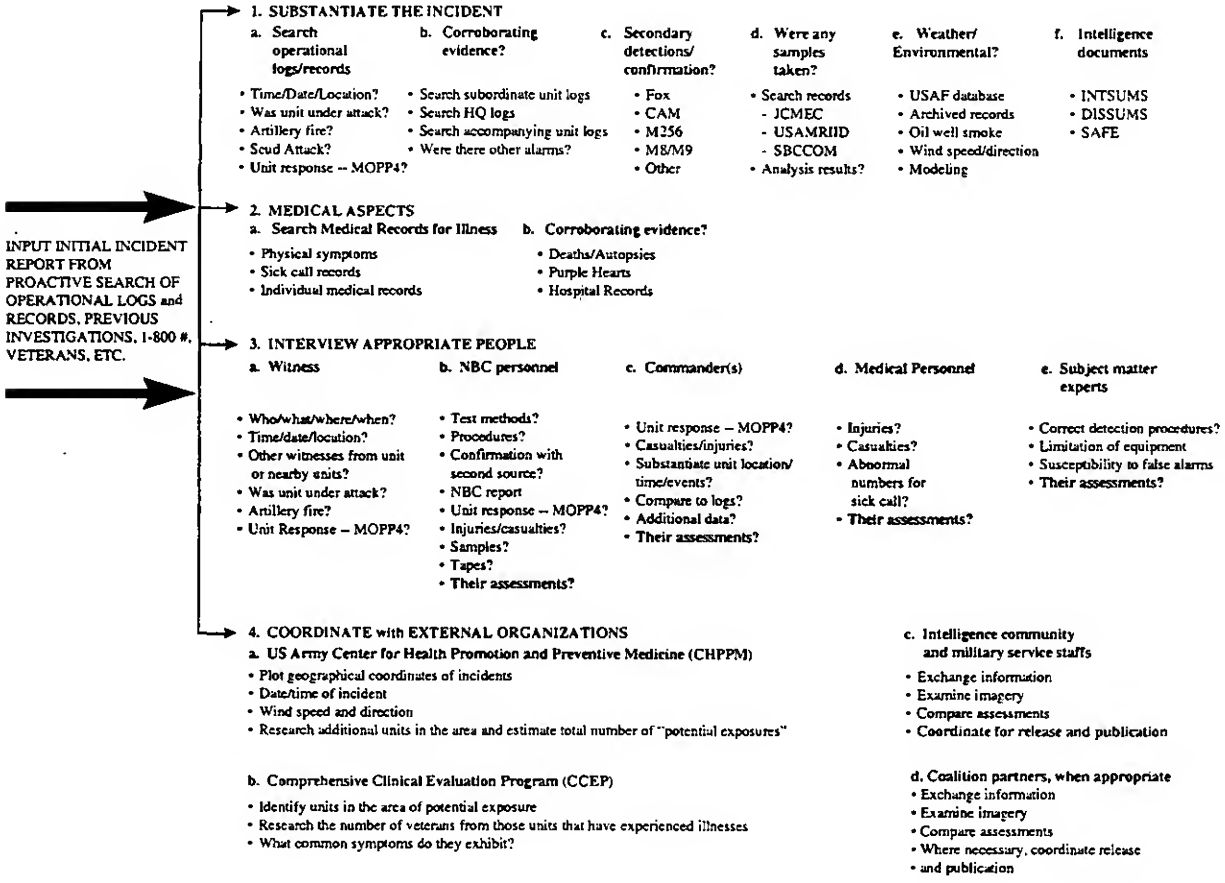

Figure 18. Chemical warfare incident investigation methodology

Alarms alone are not considered to be certain evidence of chemical warfare agent presence, nor is a single observation sufficient to validate a chemical warfare agent presence. The investigator looks for physical evidence collected at the time of the incident that might indicate that chemical agents were present in the vicinity of the incident. Such evidence might include tissue samples, body fluid samples, clothing, environmental samples of soil or vegetation, weapons parts, and Fox MM-1 tapes with properly documented spectrums.

The investigator searches available medical records to determine if anyone was injured by the incident. Deaths, injuries, sicknesses, etc., near the time and location of an incident are noted and considered. Medical experts are asked to provide information about any alleged chemical warfare agent casualties.

Interviews of those involved in or near the incident (participants or witnesses) are conducted. First-hand witnesses provide valuable insight into the conditions surrounding the incident and the mind-set of those involved, and are particularly important if physical evidence is lacking. Nuclear, biological, and chemical officers or specialists trained in chemical testing, confirmation, and reporting are interviewed to identify the unit's response, the tests that were run, the injuries sustained, and the reports submitted. Commanders are contacted to ascertain what they knew, what decisions they made concerning the events surrounding the incident, and their assessment of the incident. Where appropriate, subject matter experts also provide opinions on the capabilities, limitations, and operation of technical equipment, and submit their evaluations of selected topics of interest.

Additionally, the investigator contacts agencies and organizations that may be able to provide additional clarifying information about the case. These would include, but not be limited to:

- Intelligence agencies that might be able to provide insight into events leading to the event, imagery of the area of the incident, and assessments of factors affecting the case;
- The clinical registries of the Departments of Defense and Veterans Affairs which may provide data about the medical condition of those involved in the incident; and
- Agencies capable of computer modeling meteorological and source characterization data in cases where airborne dispersion of agent is suspected.

Once the investigation is complete, the investigator evaluates the available evidence in order to make a subjective assessment. The available evidence is often incomplete or contradictory and thus must be looked at in the total context of what is known about the incident being investigated. Physical evidence collected at the time of the incident, for example, can be of tremendous value to an investigation. Properly documented physical evidence would generally be given the greatest weight in any assessment. The testimony of witnesses and contemporaneous operational documentation is also significant when making an assessment. Testimony from witnesses who also happen to be subject matter experts is usually more meaningful than testimony from untrained observers. Typically, secondhand accounts are given less weight than witness testimony. When investigators are presented with conflicting witness testimony, they look for other pieces of information supporting the statements of the witnesses. Investigators evaluate the supporting information to determine how it corroborates any of the conflicting positions. Generally, such supporting information will fit into a pattern corroborating one of the conflicting accounts of the incident over the others. Where the bulk of corroborating evidence supports one witness more than another, that person's information would be considered more compelling.

Our assessments rely on the investigators' evaluation of the available information for each investigation. Because we do not expect to always have conclusive evidence, we have developed

an assessment scale (Figure 19) ranging from Definitely Not to Definitely, with intermediate assessments of Unlikely, Indeterminate, and Likely. The investigator will use this scale to make a tentative assessment based on facts available as of the date of the report publication. Each case is reassessed over time based on new information and feedback.

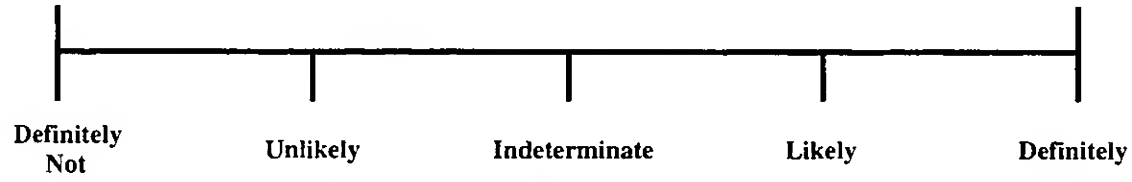

Figure 19. Assessment of chemical warfare agent presence

The standard for making the assessment is based on common sense: Do the available facts lead a reasonable person to conclude that chemical warfare agents were or were not present? When insufficient information is available, the assessment is Indeterminate until more evidence can be found.

TAB D – DoD's Modeling

The first thing DoD did for their modeling was to collect all available weather observations. Although global weather information exists for this period, atmospheric conditions were generally poorly recorded for this region during the Gulf War. For its analysis, DoD used important declassified data (e.g., from US Air Force Special Forces) not available to the CIA during the preliminary modeling. However, even this data was not sufficiently detailed to predict accurate local and regional dispersion. To address this problem, the modeling team adopted a two step process similar to that used to model possible releases at Khamisiyah to reconstruct the weather conditions in the vicinity of Ukhaydir at the time of the release:

- global scale modeling to determine general weather patterns affecting the area; and,
- regional and local (i.e., mesoscale) weather modeling using the results of the global scale models and all available observations of specific local weather. Regional and local weather models incorporate information about local weather effects specific to the particular region in question.[65,66] For example, the weather at Ukhaydir was affected not only by the local terrain but possibly also by breezes from several lakes to the north. (See Figure 2.)

In keeping with the ensemble approach, the Ukhaydir modeling effort used four weather models:

- two global scale models:
  - The National Centers for Environmental Prediction Global Data Assimilation System (GDAS);
  - The Naval Operational Global Atmospheric Prediction System (NOGAPS);

- two regional and local weather models:
  - The Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS);
  - The Operational Multiscale Environment Model with Grid Adaptivity (OMEGA).

After running these models, the modeling team had sufficiently detailed information about specific weather conditions for use in the transport and diffusion models. For example, DoD estimated that the near surface winds (approximately 10 meters above ground level) at Ukhaydir were generally light and variable for the time in question (approximately midnight on February 13, 1991, through February 16, 1991).

DoD used two different transport/diffusion models:

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[65] Global scale models usually have a spatial resolution in the order of one degree latitude/longitude, or roughly 100 kilometers, and the model domain covers the whole earth or at least one hemisphere. Because of limited spatial resolution, these models can only provide general descriptions of the weather affecting the area. As a result, the results from these global scale models are further blended with available local observations to drive regional scale models, whose spatial resolution, depending on the model and its configuration, can range from a few kilometers to tens of kilometers, to provide more detailed descriptions of local weather patterns.

[66] Central Intelligence Agency and Department of Defense, "Modeling the Chemical Warfare Agent Release at the Khamisiyah Pit (U)," September 4, 1997.

- The Second-order Closure Integrated Puff (SCIPUFF) model; and
- The Vapor, Liquid, and Solid Tracking (VLSTRACK) model.

In addition to weather data, transport/diffusion models require source characterization data and dosage information.

The source characterization was the same as that developed by the CIA for its preliminary modeling, i.e., an instantaneous release of seven gallons followed by a sustained release of 83 gallons over three days. Although the evaporation of agent from the crater would have taken place over a number of days, the decreasing release rate, as well as the generally calm weather conditions, would have limited any potential hazard areas after the first 72 hours. Dosage information determines which parts of the hazard areas represent the greatest potential danger for exposed personnel. Dosage is defined as concentration integrated over a specific time period of exposure. DoD used the general population limit to model the area of potential exposure. The general population limit is the average concentration below which the general population, including children and the elderly, could remain indefinitely with no effects. The general population limit for mustard over a 72 hour period is 0.432 milligram-minute per cubic meter of air (0.0001 x 72 hours x 60 minutes).[67] The hazard areas shown in Figures 15, 16, and 17 depict the area where the level of mustard is above the general population limit.

The modelers did not take into account certain mechanisms that could have limited the extent of any exposure area (e.g., agent decay over time such as that caused by the possible effects of exposure to sunlight). Because there was no specific information about how these mechanisms might affect the amount of agent degraded during transport and dispersion, the modelers used a more conservative approach and did not use them to limit the extent of the hazard areas.

To produce the ensemble hazard areas, the modeling team created a composite of three different combinations of weather and diffusion model simulations:

- NOGAPS/COAMPS/SCIPUFF;
- GDAS/OMEGA/SCIPUFF; and
- NOGAPS/COAMPS/VLSTRACK.

The modelers then overlaid the hazard areas produced by these three simulations and used the outermost perimeter of the union to define an ensemble hazard area.

Any assessment of the likelihood of exposure of US troops to mustard agent released from Ukhaydir depends on how close the modeled hazard areas came to known troop locations. The US Armed Services Center for Unit Records Research conducted an extensive review of Gulf War unit records to determine where units were located during February 14, 15, and 16, 1991. While impossible to recreate precisely where each servicemember was during every moment of

[67] US Army Pamphlet 40-173, "Occupational Health Guidelines for the Evaluation and Control of Occupational Exposure to Mustard Agents H, HD, and HT," August 30, 1991.

every day, Figures 15, 16, and 17 generally reflect locations where the majority of unit members were as they performed their missions.[68]

[68] See Tab F for more information on how Gulf War unit locations are recorded.

TAB E – How to Read the Hazard Area Maps

In the hazard area maps produced from DoD's follow-on modeling of the February 13/14, 1991, strike on the road, the green sections (light grey when the map is printed) represent the area that received a dosage equal to the general population limit dosage over that entire 24 hour period.

While it is not possible to know precisely where every individual was during every moment of every day, the squares on the map represent the locations of US units on the days in question. These locations may be either positions on the ground or, in a few instances, the locations of personnel engaged in helicopter attacks on enemy targets. If the maps indicate locations north of the Iraqi-Saudi Arabian border or in Kuwait before the official start of the ground war, these unit locations generally represent the locations of helicopter assaults on enemy targets during that period. Additionally, cross-border raids had been authorized by the second week of February 1991. If units reported their position during cross-border operations, that information has been captured and is represented on the hazard area maps in this narrative. See Tab F for information on how Gulf War unit locations have been derived.

Two widely accepted versions of the border between Iraq and Saudi Arabia are shown on the maps in this narrative. The familiar border separating Iraq and Saudi Arabia is a pre-1982 boundary. This is the border typically shown on maps used in our case narratives. However, the de facto boundary also shown on these maps represents the border shown on the operational maps used by US ground and air forces during the Gulf War. Some maps used during the Gulf War showed both the pre-1982 border and the de facto boundary, while others showed only the de facto boundary. On many of the maps used during the Gulf War, the de facto boundary was annotated to state that it was displayed as shown on official Iraqi and Saudi maps. This de facto border, then, generally separated Coalition and Iraqi troops during Operation Desert Shield, prior to the start of Operation Desert Storm, commonly referred to as the ground war. Therefore, US troops were aligned along the de facto boundary, rather than the pre-1982 border, before the start of the ground war.

TAB F – How Unit Locations Were Determined

The US Armed Services Center for Unit Records Research reviewed a large number of Gulf War unit records to determine unit locations, and therefore, obtain insight into locations of unit members, during the Gulf War. This review began in mid-1994 and information on unit locations has been added continuously into a database as locations are determined or corrected. The Center gathers unit location information from a wide variety of sources, including unit history data archives, operational logs, situation reports, after action reports, and historical reports.

To identify veterans who may have been under the downwind hazard areas, it was essential to determine their units' locations during the period in question. Although veterans were either assigned or attached to specific units during the Gulf War, a unit's location on a specific day may not necessarily pinpoint where an individual soldier was on that day. For example, the precise location of a soldier on patrol or in transit to another location would rarely be recorded.

TAB G – Comparison of Preliminary and Follow-on Modeling for February Airstrike

The CIA only modeled a preliminary hazard area for the possible release on the first day after the February 13/14th strike. The direction and size of this hazard area differ from the direction and size of the hazard area produced by DoD's follow-on modeling for the same time frame. (See Figures 20 and 21.) It is important to note that neither hazard area approaches US troop locations along the Iraqi-Saudi Arabian border.

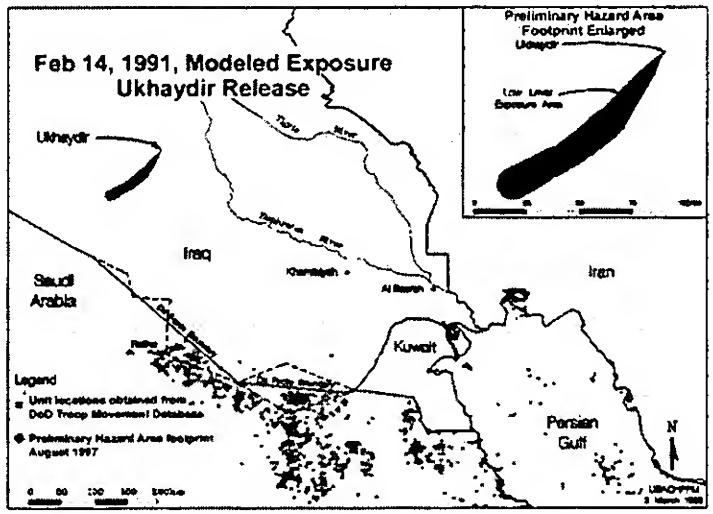

Figure 20. CIA's preliminary modeling results for the February 13/14th airstrike

The differences in the shape and direction of the hazard areas derive from the fact that the CIA used only a single weather model and a single transport/diffusion model, rather than an ensemble of models, as well as the differences in the meteorological information used in the preliminary and follow-on modeling. The CIA intended the preliminary modeling to be a quick turnaround analysis providing a first look at the potential exposure area. As such, the preliminary meteorological models used only unclassified operational weather data.

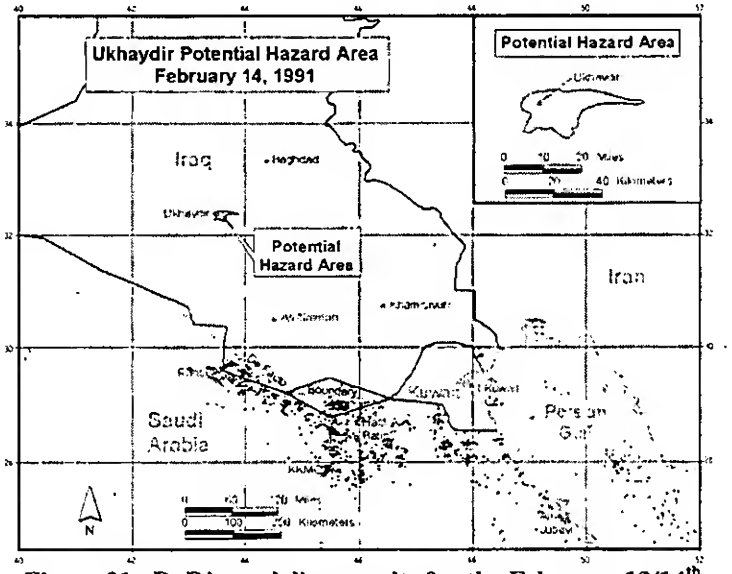

Figure 21. DoD's modeling results for the February 13/14th airstrike, Day 1

As discussed in the narrative, the follow-on modeling used more comprehensive weather data. In addition to the unclassified information used in the preliminary modeling, the follow-on modeling used more detailed declassified information from US Air Force archives and took into account the local weather effects of the nearby lakes and the terrain around Ukhaydir.

The follow-on modeling also used a more recent version of the OMEGA meteorological model. At the time of the preliminary modeling (August 1997), OMEGA was undergoing substantive

enhancements. The preliminary modeling used version 2.0 of the OMEGA model, while the follow-on modeling used the updated and improved version 3.5 as part of its ensemble of weather models. The differences between the preliminary and follow-on hazard areas can be attributed, in part, to the enhancements in the OMEGA meteorological model as well as to the more complete and detailed weather information in the follow-on modeling.

Environmental Exposure Report

Particulate Matter

Environmental Exposure reports are reports of what we know today about certain events of the 1990-1991 Gulf War. This particular environmental exposure report focuses on US personnel exposure to particulate matter and the related health effects that may be associated with this exposure. This is an interim, not a final, report. We hope you will read this and contact us with any information that would help us better understand the issues reported here. With you help, we will be able to report more accurately on the subject of particulate matter exposures experienced during the Gulf War. Please contact my office to report any new information by calling

1-800-497-6261

Bernard Rostker
Special Assistant for Gulf War Illnesses
Department of Defense

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Last Update: July 12, 2000

Many veterans of the Gulf War have expressed concern their unexplained illnesses may result from their experiences in that war. In response to veterans' concerns, the Department of Defense (DoD) established a task force in June 1995 to investigate those incidents and circumstances relating to possible causes. The Office of the Special Assistant to the Deputy Secretary of Defense for Gulf War Illnesses assumed responsibility for these investigations on November 12, 1996, and gathered information on particulate matter exposures.

To inform the public about the progress of this office, the Department of Defense publishes on the Internet and elsewhere accounts related to the possible causes of illness among Gulf War veterans, along with documentary evidence or personal testimony used in compiling the accounts. This environmental exposure report is such an account.

TABLE OF CONTENTS

I. OVERVIEW

US personnel deployed to the Kuwait Theater of Operations (KTO) during Operations Desert Shield/Storm were potentially subjected to several environmental and man-made factors capable of causing adverse health effects. While all environmental media (i.e., air, water, and soil) were affected, the air quality in the region was a primary concern. The poor air quality in specific areas of the KTO was due to various factors arising from both natural and man-made sources, including: blowing sand from the desert environment; emissions from petro-chemical industrial sites in Kuwait and Saudi Arabia, civilian and military vehicle traffic, oil fields and refineries; and the Kuwait oil well fires, to name a few.

The Office of the Special Assistant for Gulf War Illnesses investigated the events surrounding the Kuwait oil fires and their potential impacts on human health. The findings and results of this investigation were published on the Department of Defense's GulfLINK website in November 1998.[1] During the course of the oil fires investigation researchers determined that the principal contaminants of concern to which US military personnel were exposed were the soot and by-products of combusted crude oil and also the high levels of fine dust and sand particles present in this region of the world. These particles, collectively referred to as particulate matter, arise primarily from natural sources; an intensive air quality monitoring program conducted shortly after the war verified their presence.

As a result of this monitoring program, a substantial body of data was gathered that not only has assisted post-war efforts to assess the effects of the hydrocarbons contained in the oil well fire smoke on human health and the environment, but also has provided meaningful data on the particulate matter levels to which US military personnel were exposed during their deployment to Kuwait and Saudi Arabia.

These data indicate that while combustion by-products from burning crude oil (e.g., oxides of sulfur and nitrogen, carbon monoxide, carbon dioxide, non-combusted hydrocarbons, etc.) contributed to the poor ambient air quality immediately downwind of the burning oil fields, the principal contaminant of concern was particulate matter.[2] Particulate matter levels often were twice those considered safe by health professionals. Other contaminants generally were lower than US levels or below standards established to protect human health. While pre-war monitoring data indicate that the levels for particulate matter are among the highest in the world,[3] the levels are "normal" for the region and result primarily from sand, and to a lesser extent, man-made sources as noted above.

The Oil Well Fire Environmental Exposure Report prepared by the Office of the Special Assistant for Gulf War Illnesses identified several issues requiring additional research to resolve whether US military personnel exposed to contaminants from natural and man-made sources

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[1] Special Assistant for Gulf War Illnesses, "Oil Well Fires," Environmental Exposure Report, November 1998.
[2] US Environmental Protection Agency, Kuwait Oil Fires: Interagency Interim Report, Washington, D.C., 1991, p. A-2.
[3] Final Report to the Under Secretary of Defense (Acquisition & Technology), Report of the Defense Science Board Task Force on Persian Gulf War Health Effects, June 1994, p. 50.

could lead to long-term illness or explain any of the undiagnosed symptoms some Gulf War veterans have reported. One area identified for further research was the health effects associated with exposure to particulate matter. Because information on the long-term health effects from exposure to particulate matter generally is lacking in the literature, researchers believed this issue warranted a separate investigation.

This report presents the results of such an investigation and discusses what we currently know about US personnel exposures to particulate matter during the Gulf War to determine whether a causal relationship exists between exposures to particulate matter and the long-term unexplained illnesses some Gulf War veterans report.

In general, existing studies on the chronic or long-term effects of particulate matter exposure are inconclusive or inconsistent in their findings. To address this limitation the Office of the Special Assistant for Gulf War Illnesses commissioned, as part of this current investigation, a medical literature search and exposure assessment on the effects of particulate matter. This study, prepared by Thomas, et al. (2000)[4] for the Office of the Special Assistant for Gulf War Illnesses, specifically examines the chronic or long-term effects associated with the silica (the primary component of sand) and soot content of particulate matter as a means of estimating the potential long-term effects of particulate matter exposure.

The Thomas report examines the respirable silica and soot concentrations contained in particulate matter (as measured in samples taken at several points in Kuwait and Saudi Arabia in 1991) and estimates US personnel exposures. The authors then compare these estimates with accepted US exposure guidelines to estimate the potential health risks to Gulf War veterans. The Thomas report's overall objective is to describe what the medical literature says about this exposure and determine the likelihood of the onset of chronic or long-term health effects arising from exposure to the silica and soot contained in particulate matter during the Gulf War. The Thomas report was peer reviewed by leading scientists and subject matter experts from industry, academia, and the US Environmental Protection Agency (US EPA) and stands as the most current reference to the health effects of the air quality contaminant most prevalent in the Gulf War.

Subsequent sections of this report will discuss: 1) background issues related to US personnel exposure to particulate matter; 2) the results of air monitoring studies conducted in Kuwait and Saudi Arabia in 1991; 3) US air quality standards governing particulate matter exposures; 4) general health effects associated with exposures to particulate matter; 5) an overview of the Thomas report; and 6) areas requiring further investigation or research. TAB A contains acronyms, abbreviations, and a glossary of terms used in this report; TAB B contains references used in compiling this report.

II. BACKGROUND

[4] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War," May 2000.

Particulate matter is a generic term applied to a broad class of chemically, physically, and biologically diverse substances spanning a range of particle sizes. Typically, airborne particulate matter ranges in size from molecular clusters of less than 0.001 microns (μm) to particles more than 50 μm in diameter. A 10 μm particle is roughly one-sixth the width of a human hair. These particles are composed of chemically diverse materials, and are transported in the air as solid particles or liquid droplets.[5]

Particle size analyses conducted on air samples taken in 1991 at several locations in Kuwait and Saudi Arabia (see Section III) indicated that there was a significant mass of particles in the respirable size range (i.e., less than 10μm in aerodynamic equivalent diameter). Particles in this size range (commonly referred to as PM_{10} – see the glossary) have the potential for entering the thoracic region (see the glossary) of the respiratory tract and will deposit either in the tracheobronchial region (conducting airways of the lung) or in the pulmonary region (alveolar region where gas exchange occurs). This will be a function of the particle aerodynamic equivalent diameter (AED – see the glossary) and collection efficiency of the respiratory tract for a given particle AED. When found at high concentrations in the ambient environment, and under conditions of extended exposure, these particles have been associated with changes in lung function, damage to lung tissue, and altered respiratory defense mechanisms (e.g., an impaired ability to naturally eject foreign matter via exhalation). In an occupational setting, exposures (with higher concentrations and/or longer durations) have resulted in similar, if not more severe, health effects. It should be understood that dose and duration of exposure are equally important factors when assessing health effects.

While the oil fires were a contributor to the particulate matter levels (primarily in the form of soot) observed in 1991, particulates also originated from a number of other sources during the same time frame. They were emitted directly from combustion sources (e.g., gasoline engines and crude oil refining operations), wind blown sand, or from the natural transformation in the atmosphere of gaseous emissions such as sulfur oxides, nitrogen oxides, and volatile organic substances. Based on the analysis of samples collected by the US Army Environmental Hygiene Agency (USAEHA) (currently referred to as the US Army Center for Health Promotion and Preventive Medicine) shortly after the Gulf War, analysts have determined that roughly 75% of the particulate matter originated from sand common to this part of the world. Another 23% of the total were soot from the oil fires. The remainder was from miscellaneous sources. [6]

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[5] US Environmental Protection Agency, 40 CFR Part 50, National Ambient Air Quality Standards for Particulate Matter; Final Rule, Federal Register, Friday July 18, 1997, p. 3.

[6] US Army Environmental Hygiene Agency, "Final Report – Kuwait Oil Fire Risk Assessment. No. 39-26-1192," February 1994, p. G-30, 33, 34.

Sand and dust storms are problematic year round in this area of the Middle East, but are worse during the summer when the northwesterly *shamal* winds occur with greater frequency and intensity.[8] Because sand and dust can obscure vision (without causing actual injury), irritate the skin and sensitive membranes of the eyes, nose, and throat, and aggravate sinus and asthmatic conditions, it was necessary for US personnel in the Gulf to protect themselves against wind blown sand. Consequently, standard personal protective items available to most US personnel included goggles and cravats (large kerchief-type cloths) or similar protection for the airways. Various directives and policy statements directed or advised the use of these items.[9, 10, 11]

> *While still in Iraq following the cease-fire, a severe sandstorm occurred that lasted all day. The sand and dust was so dense that [we] could not see objects even 30 meters distant...our guns were deployed 35 meters apart, and we could not see the guns on either side of our position.*
>
> *- Gulf War Veteran*[7]

Because many US personnel trained, operated, and lived in the desert, health personnel were concerned about the possible adverse health effects of being exposed to high levels of blowing and suspended sand. The grain size of the sand was characteristically small, and some personnel with pre-existing respiratory problems experienced aggravated symptoms. For example, hospital records indicate that US personnel frequently suffered from acute upper respiratory infections as well as coughs, sore throats, sneezing, and runny noses.

It was unlikely that all respiratory complaints experienced during the Gulf War were solely the result of exposure to high particulate matter levels, however. One study conducted among 2,598 personnel stationed in northern Saudi Arabia found that the type of structure in which an individual slept might have been as important a determinant for developing respiratory complaints as exposure to outdoor air pollutants. Personnel who slept in air-conditioned buildings, for example, were much more likely to develop a cough and sore throat than those billeted in tents and warehouses.[12]

Similar findings have been observed in US military training camps where recruits living in modern, energy-efficient barracks with closed ventilation systems were found to be at higher risk from respiratory-transmitted infections. These studies found that personnel living in tightly constructed buildings exhibited more symptoms, because in closed and crowded spaces they were more likely to pass respiratory infections among each other. The Navy Forward Laboratory

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[7] Lead Sheet No. 22581, Interview with a Gulf War Veteran, April 1999.

[8] US Army Medical Intelligence Overview – Eastern Saudi Arabia, Subject: Medical Intelligence Overview – Eastern Saudi Arabia, Performance Degradation Due to Climatic Factors, published on GulfLink: www.gulflink.osd.mil/declassdocs/.

[9] Army Central Command. XVIII Corps, Information paper, Subject: "Hydrogen Sulfide (H2S)," November 1990, published on GulfLink: www.gulflink.osd.mil, p. 3.

[10] Memorandum from Kuwait Environmental Restoration Office, US Army Corps of Engineers, to Staff Members/DAG Team Chiefs, Subject: "Health threat from Oil Well Fires – Information Paper," March 1991, published on GulfLink: www.gulflink.osd.mil, p. 9.

[11] US General Accounting Office, Health Effects of the Kuwait Oil Fires, GAO/HRD-92-50, January 1992, p. 4.

[12] Richards A.L., K.C. Hyams, and D.M. Watts et al: "Respiratory Disease among Military Personnel in Saudi Arabia during Operation Desert Shield," American Journal of Public Health, 1993, 83:1326-1329, p. 1328.

found that the respiratory infections observed in the KTO during the Gulf War were caused by well-known, common viral and bacterial agents.[13]

The rates of outpatient treatment were slightly higher early in the Gulf War deployment, when personnel tended to be crowded together in transport aircraft, ships, ports of debarkation, and rally or assembly areas. Respiratory disease rates showed a rapid decline as forces dispersed into field positions, but rose again when the weather turned cold. These acute respiratory illness patterns are similar to what is typically seen at military installations in the US.[14]

The health issues surrounding the short- and long-term exposures to particulate matter are discussed in Section V of this report.

III. RESULTS OF AIR QUALITY MONITORING IN THE GULF

In the immediate aftermath of Operation Desert Storm, numerous efforts were undertaken to assess the air quality in Kuwait and Saudi Arabia, primarily in the areas immediately downwind of the burning oil wells. The US Interagency Air Quality Assessment Team (USIAAT), USAEHA, and various national teams under a World Meteorological Organization program collected air quality sampling and monitoring data. Collectively, the data from these programs indicated that, with the exception of particulate matter, pollutant levels were surprisingly low. For example, a comparison was made between the 1991 median volatile organic compound (VOC) levels in cities in Kuwait and Saudi Arabia and levels observed in several cities in the US for the same time period. Overall, with the exception of particulate matter concentrations, the median VOC concentrations for benzene, toluene, ethyl benzene, and the xylenes from the Kuwaiti and Saudi Arabian sites were near or below the respective concentration values for the US cities.[15]

The largest and most comprehensive of the air-monitoring programs was conducted by the USAEHA. At the request of the US Army Surgeon General, the USAEHA developed an air sampling program to determine the magnitude and extent of pollutants released into the atmosphere from the burning oil wells. Sampling, conducted at eight locations in Kuwait and Saudi Arabia, began in early May 1991 and continued through October 1991. The sampling focused on the expected by-products of crude oil combustion. In addition, the USAEHA also collected PM_{10} air samples using high-volume samplers.

To further assess ambient air quality in the region, the USAEHA collected additional PM_{10} samples in the November to December 1991 timeframe at two sites after the oil well fires were extinguished. These additional samples provided "baseline" information on ambient air quality under more typical conditions; they helped differentiate the added inhalation risk posed by the oil

[13] Hyams, K.C., A.L. Bourgeois, J. Escamilla , J. Burans, and J.N. Woody, "The Navy Forward Laboratory During Operations Desert Shield/Desert Storm," Military Medicine 1993, 158:729-732.
[14] "Military Medicine in Operations Desert Shield and Desert Storm: the Navy Forward Laboratory, Biological Warfare Detection, and Preventive Medicine," web site: www.gulflink.osd.mil/medical/med_navy.htm.
[15] US Army Environmental Hygiene Agency, "Interim Report: Kuwait Oil Fire Health Risk Assessment," No. 39-26-L192-91, June 1991, p. ES-3.

well fires, as distinct from the "everyday" pollution sources in the region. In general, the USAEHA frequently observed high levels of airborne particulate matter (sand and soot) at several monitoring sites. Table 1 presents the PM_{10} average and the maximum observed concentrations at the eight sampling locations. These concentrations are 24-hour averages and represent the air quality during the May to October 1991 period, in which the oil wells were burning. As such, they represent a "worst-case" condition, in that the particulate levels reflect the contributions from various background sources as well as the oil fires.

Table 1. PM_{10} Concentrations by Site[16]

Air Monitoring Location	Average Concentration[17] ($\mu g/m^3$)	Maximum Concentration[18] ($\mu g/m^3$)
US Embassy, Kuwait	670.6	1105.7
King Khalid Military City, Saudi Arabia	298.6	923.5
Khobar Towers, Saudi Arabia	267.8	433.8
Al Jubayl, Saudi Arabia	279.6	360.7
Military Hospital, Kuwait	497.1	759.0
Al Eskan Village, Saudi Arabia	271.1	697.5
Camp Thunderock, Kuwait	264.6	365.7
Ahmadi Hospital, Kuwait	367.5	544.1

The PM_{10} samples were analyzed to determine the chemical and physical properties of the particulate matter. This information was used in turn as part of a detailed risk assessment related to Department of Defense (DoD) military and civilian exposures to contaminants associated with the burning oil wells.

Analysis of the chemical composition of the samples indicated that roughly 75% of the airborne particulate matter measured in Kuwait and Saudi Arabia in 1991 consisted of clays, primarily calcium and silica. That is, it originated from the sand indigenous to this part of the world. Another 10% to 23% were carbon (soot) that originated from a combination of sources that included the oil fires and the various industrial sources, and less than 10% originated from salt

[16] US Army Environmental Hygiene Agency, "Final Report – Kuwait Oil Fire Risk Assessment," No. 39-26-1192, February 1994, Appendix G: Table G-2-19-28.

[17] These values represent the average of 24-hour samples collected from May to October 1991.

[18] These values represent the 24-hour maximum concentrations observed.

and miscellaneous sources.[19] Figure 1 shows the particulate matter composition in the Kuwaiti and Saudi Arabian air samples taken in 1991. These values represent total percent composition of each component without regard to their respirable size fraction (i.e., that fraction capable of being respirated into the lower portion of the respiratory tract). The respirable PM_{10} air samples were subsequently analyzed for the silica component.

Although high levels of particulate matter were observed, these concentrations fell within a range consistent with background levels observed in Kuwait where the average level of PM_{10} is nearly 600 $\mu g/m^3$, the highest in the world.[20]

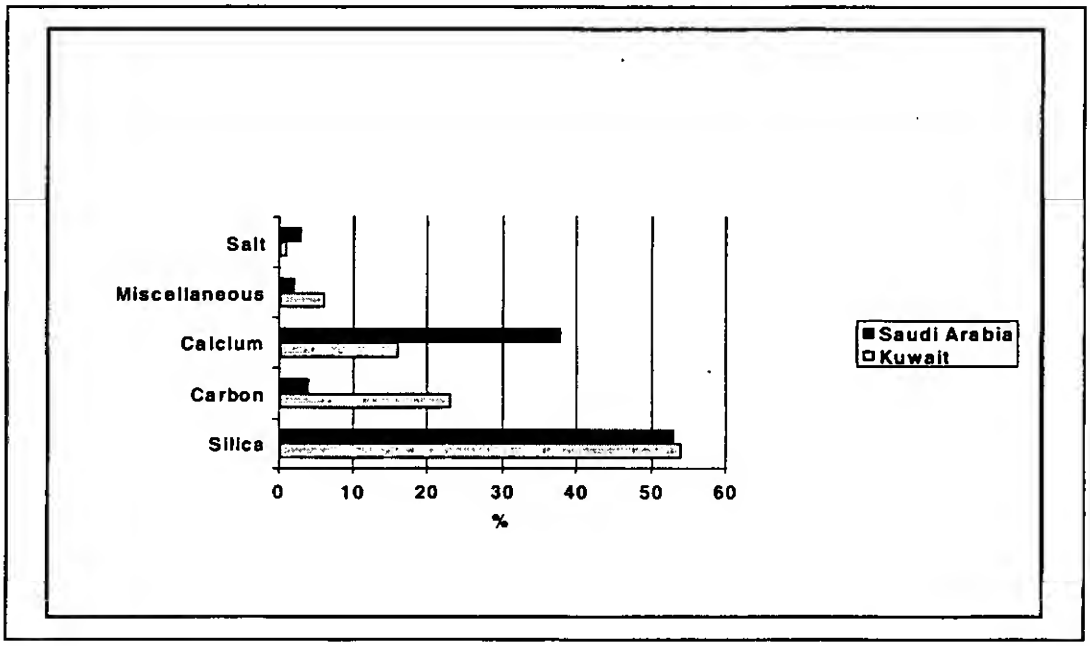

Figure 1. Particulate Composition of Air Samples in Saudi Arabia and Kuwait[21]

IV. PARTICULATE MATTER AIR QUALITY STANDARDS

Exposure to ambient particulate matter has been associated with a range of adverse health effects; including: premature mortality, aggravation of existing respiratory conditions, changes to lung tissues and structures, and altered respiratory defense mechanisms. These responses to exposure are a function of the exposure concentration, the duration of the exposure, and the amount absorbed in the body (i.e., dose over time).

[19] US Army Environmental Hygiene Agency, "Final Report – Kuwait Oil Fire Risk Assessment," No. 39-26-1192, February 1994, p. G-30, 33, 34.
[20] US Department of Defense, Office of the Under Secretary of Defense for Acquisition and Technology, "Report of the Defense Science Board Task Force on Persian Gulf War Health Effects," June 1994, Published on GulfLINK (http://www.gulflink.osd.mil), p. 50.
[21] Spektor, D.M., "A Review of the Scientific Literature as it Pertains to Gulf War Illness, Oil Well Fires", RAND, Volume 6: 1998, p. 25.

As a preventive step against these adverse health effects, the US Environmental Protection Agency (EPA) established a National Ambient Air Quality Standard (NAAQS) for particulate matter. US ambient (NAAQS) and American Council of Government Industrial Hygienists (ACGIH) occupational standards were established to protect the general US population and to provide protection in the workplace environment. Ambient standards were designed to protect populations that included the sick, the elderly, and the very young and would therefore provide a more conservative level of protection for US troops.

The EPA established the first NAAQS for particulate matter in 1971. It targeted the total suspended particulate (TSP) mass per unit volume of air, without regard to the chemical composition of the particles. In 1987, the EPA revised the standard, changing the indicator from TSP to PM_{10}. The EPA decided that PM_{10} was a better public health indicator than TSP because it targeted particles small enough to enter and deposit in the tracheobronchial region or penetrate deeper in the lung into the pulmonary region (alveolar region where gas exchange occurs) if the particles are small enough (about 10 μm AED or less). The PM_{10} standard, like the TSP standard, was based on mass without regard to chemical composition.[22]

The 1987 EPA criteria for PM_{10} is 150 $\mu g/m^3$ averaged over 24 hours and 50 $\mu g/m^3$ averaged annually.[23] The data collected in 1991 by the USAEHA shows that the PM_{10} concentrations at Saudi Arabian and Kuwaiti monitoring stations consistently exceeded the EPA 24-hour criteria of 150 $\mu g/m^3$ (see Table 1).

V. GENERAL HEALTH EFFECTS AND ISSUES ASSOCIATED WITH EXPOSURE TO PARTICULATES

A. Background

Particles of about 10 μm or less in aerodynamic equivalent diameter are capable of reaching the alveoli (air sacks in the lung),[24] and those measuring between 0.5 and 1.0 microns aerodynamic diameter have the highest possibility, percentage-wise, of being deposited in the alveoli.[25] The lower respiratory tract clearance mechanism is highly efficient and capable of completely eliminating all particles smaller than five microns as long as the airborne concentration does not

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[22] The standards were again revised in 1997. The levels for the PM_{10} standards were retained, however, new standards for $PM_{2.5}$ (i.e., particles less the 2.5 microns in diameter) were added. It was felt that the $PM_{2.5}$ size fraction is a better surrogate for those components linked to mortality and morbidity effects. The new standards have been challenged and are in litigation leaving the 1987 PM_{10} standard in effect. The new $PM_{2.5}$ standards are in effect for limited purposes; however, since the 1991 air samples were measured only for PM_{10} and not $PM_{2.5}$ only the PM_{10} standards are used for comparison in this report.

[23] USEPA, Code of Federal Regulations, "Federal Register, National Ambient Air Quality Standards for Particulate Matter; Final Rule," Washington, DC: US Government Printing Office, Office of the Federal Register 1997, 40 CFR Part 50.

[24] Rabovsky, J., "The Laboratory Studies On Silica Induced Toxicity and Relationship to Carcinogenicity," Journal of Exposure Analysis and Environmental Epidemiology, Vol. 7, No. 3, 1997, p. 269.

[25] Parkes, W.R., "Inhaled Particles and their Fate in the Lungs," Occupational Lung Disorders (2nd Ed.), Boston, Butterworths, 1983, p. 48-49.

exceed 10 particles per cubic centimeter. However, in environments with a much higher concentration of airborne particulates, say, 1000 particles per cubic centimeter, the efficiency level of the lower respiratory tract clearance system declines somewhat, so that only 90 percent of the particles will likely be eliminated.[26]

Overall, health risks posed by inhaled particles are influenced by the concentration of particulate matter in the air, the duration of exposure, the penetration and deposition of particles in the various regions of the respiratory tract, and the body's biological responses to these deposited materials. The largest particles are deposited in the air passages of the nose and sinuses (i.e., upper respiratory tract), with somewhat smaller particles depositing in the large and medium bronchi (i.e., middle respiratory tract). Still smaller particles can reach the gas exchange region of the lung (i.e., lower respiratory tract). In general, the risks of adverse health effects from the deposition of typical ambient fine particles in the lower respiratory tract are markedly greater than those from depositions in the upper air passages of the nose and sinuses.

Numerous studies have appeared in the recent literature on particulate matter epidemiology and have demonstrated an association between ambient particulate matter exposures and various acute health outcomes. Such outcomes include, for example, hospital admissions, increased respiratory symptoms, and decreased lung functions.[27] Findings also suggest that: 1) infants, children, and the elderly may represent subgroups at higher risk for ambient particulate matter exposure effects; 2) cardiovascular causes of death and hospitalization in older adults may be a component of particulate matter-attributable mortality; 3) particulate matter health effects have been reported to be associated with several different particulate matter size fractions; 4) health effects may occur at different time scales for exposure to PM_{10}.[28]

Epidemiology findings in the literature indicate that risk of death and the risk of the onset of disease due to lower respiratory disease (e.g., pneumonia) is increased by ambient particulate matter exposures. This may be due to exacerbation, by particulate matter, of a previously existing respiratory disease. Exposure to high levels of particulate matter may also increase susceptibility to infectious disease by decreasing clearance, impairing macrophage function, or through other specific and nonspecific effects on the immune system. The epidemiologic findings also indicate that individuals with preexisting infectious respiratory disease (e.g., pneumonia) are at increased risk for particulate matter effects.[29]

While the focus of this report is on the exposures that may have resulted in the long-term unexplained illnesses reported by some Gulf War veterans, short-term inhalation exposures are

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[26] US Navy Bureau of Medicine, "Silicosis and Operational Exposures to Dust and Sand," 1990, http://www.gulflink.osd.mil/declassdocs/bumed/19961211/120396_sep96_decls12_0002.html.

[27] US Environmental Protection Agency, "Air Quality Criteria for Particulate Matter," Vol 3, National Center for Environmental Assessment, Office of Research and Development, Research Triangle Park, NC, April 1996, p. 13-62.

[28] US Environmental Protection Agency, "Air Quality Criteria for Particulate Matter," Vol 3, National Center for Environmental Assessment, Office of Research and Development, Research Triangle Park, NC, April 1996, p. 13-105, 13-119, 13-120, 13-121.

[29] US Environmental Protection Agency, Office of Research and Development, "Air Quality Criteria for Particulate Matter (Draft)," Volume I, October 1999, p. 1-15.

also examined as a means of explaining some of the acute symptoms experienced by Gulf War veterans during and shortly after the war.

Dermal (skin) exposures to sand and soot can produce short-term, reversible symptoms. Anecdotal information suggests that some personnel experienced rashes, skin irritation and scaling. As noted by Thomas et al (2000), particulates containing silica in particular are associated with specific types of dermatitis and skin inflammation.[30]

1. Acute Effects Associated with Particulate Matter Exposure

The inhalation of ambient levels of particulate matter observed in the KTO could have resulted in several acute symptoms and could have aggravated asthmatic conditions in some personnel. A number of recent studies have been conducted that examine the health effects associated with acute or short-term exposures to particulate matter.[31] Daily lung function and/or respiratory symptoms were associated with changes in ambient PM_{10} concentrations. These studies examined different health effect end-points for two study groups: 1) those who suffered from asthma; and 2) those who did not. Results were presented for the following end-points: 1) upper respiratory symptoms, 2) lower respiratory symptoms, or 3) cough. In general, study results indicated the following reversible symptoms as a result of acute exposures: cough, runny nose, phlegm, wheezing, and shortness of breath. A number of particulate matter exposure studies using different study groups are summarized by EPA (1999).[32] These studies related PM_{10} concentrations to observed health effects.

Adverse health effects from acute exposures to PM_{10} may be confounded by the presence of other pollutants making it difficult to estimate that portion of risk attributable solely to PM_{10}. However, analytical results of air quality samples taken in the KTO in 1991 do not indicate that other air contaminants were at levels of concern.[33,34,35] Nevertheless, uncertainties persist with this type of analysis suggesting that this issue is a candidate for further research.

2. Chronic Effects Associated with Particulate Matter Exposure

Chronic pulmonary function studies are less numerous than acute studies and the results are inconclusive and in some cases inconsistent in findings. Some studies show effects for some

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[30] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War," May 2000, p. 21.

[31] US Environmental Protection Agency, "Air Quality Criteria for Particulate Matter ," Vol. 3, National Center for Environmental Assessment, Office of Research and Development, Research Triangle Park, NC, April 1996, p. 13-62.

[32] US Environmental Protection Agency, Office of Research and Development, "Air Quality Criteria for Particulate Matter (Draft)," Volume I, October 1999.

[33] Presidential Advisory Committee (PAC) on Gulf War Veterans' Illnesses: Final Report. Washington, D.C.: US Government Printing Office, December 1996, Published on GulfLINK (http://www.gulflink.osd.mil), p. 100.

[34] US Army Environmental Hygiene Agency, Interim: Kuwait Oil Fire Health Risk Assessment. No. 39-26-1192-91, June 1991, p. ES-3.

[35] Institute of Medicine, Health Consequences of Service During the Gulf War: Recommendations for Research and Information Systems, National Academy Press, 1996, p. 46.

endpoints, but other studies fail to find for the same effects.[36] The limited number of studies that have been completed have used children as the study group. None of the recent studies have focused on a study population similar in age, health, and physical ability to that of Gulf War veterans. Therefore some other means of estimating the chronic effects of exposure is necessary and will be discussed in the next section.

B. Particulate Matter Components of Concern

Since airborne particulate matter is not a single pollutant, but rather a varying mixture of pollutants each with its own subclass of different chemical species, it is difficult to estimate the total risk of adverse health effects from exposure to particulate matter based solely on the analysis of its individual component species. That is, the risks are not necessarily additive. However, a reasonable estimate of the chronic or long-term risks can be made by focusing on those components that are: 1) significant from a total mass standpoint (i.e., they represent a significant size fraction of the sample); 2) capable of inducing a physiological change (i.e., they are capable of inducing changes or damage to lung tissue and cells); and 3) were associated with or originated from a source that potentially represents a major health concern (e.g., oil well fire smoke).

With these factors in mind, silica and soot have been identified as potential contaminants of concern as found in the particulate matter concentrations measured in air samples taken in the KTO in 1991. In an occupational environment (which typically involved a long-term exposure) both contaminants have been found to result in respiratory distress, often leading to chronic effects, and reduced pulmonary function. Because of the inconsistencies and uncertainties associated with the chronic health effects studies noted previously, an examination of these constituents may be useful to estimate the relationship between particulate matter exposure and potential chronic effects. In other words, could the short-term exposures experienced by US personnel to particulate matter containing silica and soot be a source of some of the unexplained adverse health effects reported by some Gulf War veterans? Subsequent sections of this report examine this issue.

1. Silica

Silica exposures and associated health effects have been studied extensively in an occupational environment. The deposition of silica containing dust in the lungs has been researched and reported among the inhabitants of the Saharan, Libyan, Negev and Arabian Deserts. After years of exposure, individuals in these populations tend to develop a benign, non-progressive pneumoconiosis (disease of the lung characterized by fibrosis). This condition, sometimes referred to as Desert Lung Syndrome, differs from occupational silicosis (as found in some industrial or mining settings) in that it is asymptomatic (does not produce symptoms of disease) and does not progress or worsen with time. The benign nature of the condition has been

[36] US Environmental Protection Agency, "Air Quality Criteria for Particulate Matter," Vol 3, National Center for Environmental Assessment, Office of Research and Development, Research Triangle Park, NC, April 1996, p. 13-65.

attributed to the difference between "old dust" and "new dust."[37] Old sand dust particles have surfaces that have been weathered or transformed over time. New dusts are particles of more recent origin; that is, they are freshly fractured (i.e., broken, sharp, and exposing new surface area).

Freshly fractured silica (caused by crushing, grinding, blasting, etc.) is more biologically reactive, that is, the relatively non-weathered surfaces of silica can cause a chemical-biological reaction with, and damage to the DNA in lung tissue and thus is more likely to induce an adverse effect in living tissues and cells.[38] Exposure to freshly fractured silica may occur in a variety of occupations, including foundry work, granite work, mining and tunneling, and ceramic industry work.

Analytical data developed from samples of particulate matter collected after the Gulf War did not differentiate between "old" and "new" dust. Although the Gulf War exposures probably involved "old" dust, Thomas et al, in determining risks associated with exposure to silica containing particulate matter, adopted a conservative approach that assumed all silica was "new" or freshly fractured.[39]

In the workplace long-term or chronic-exposures to respirable crystalline silica, however, have been shown to cause silicosis. Silicosis is a disease that produces fibrous tissue in the lungs and is caused by the inhalation of freshly fractured crystalline silica.[40,41] The alveolar macrophages of the lungs ingest the deposited silica particles. Silica induces lung fibrosis by causing cell breakdown within the macrophage, macrophage death, and the release of collagens (insoluble proteins formed in the lungs that may eventually lead to lung scarring).[42] Silicosis is a chronic disease that may progress for decades before significant or detectable respiratory symptoms develop.

A review of the medical databases (e.g., MEDLINE, TOXLINE) indicates that there are no reports of silicosis from desert exposures among US military personnel. A review of the DoD Incident Reporting Line and Comprehensive Clinical Evaluation Program databases produced similar results.

There are, however, references in the general literature to the so-called "Desert Lung Syndrome." Korenyi-Both, et al. (1992) report on an acute desert-related disease caused by a mixture of fine sand and pigeon droppings.[43] The authors theorized that the sand triggered an extreme allergic

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[37] Bar-Ziv, J. and G.M. Goldberg, "Simple Siliceous Pneumoconiosis in Negev Bedouins," Archive of Environmental Health, 1974, vol. 29, p. 124.

[38] Vallyathan, V., X. Shi, N.S. Dalal, W. Irr, and V. Castranova, "Generation of Free Radicals from Freshly Fractured Silica Dust," American Review of Respiratory Disease, 1988; vol. 138, p. 1213.

[39] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War," May 2000, p. 19.

[40] Fraser, R.G., J.A.P. Pare, P.D. Pare, R.S. Fraser, G.P. Genereux, Diagnosis of Diseases of the Chest (3rd Ed.), Philadelphia, W.B. Saunders Co., 1990 (p. 2282-2307).

[41] Landrigan, P.J., "Silicosis," in Occupational Medicine: State of the Art Reviews, 1987, vol. 2, p. 319.

[42] "Silicosis and Operational Exposures to Dust and Sand," Navy Bureau of Medicine, 1990, http://www.gulflink.osd.mil/declassdocs/bumed/19961211/120396_sep96_decls12_0002.html.

[43] Korenyi-Both, A.L., A.C. Molnar, and R. Fidelus-Gort, "Al Eskan Disease: Desert Storm Pneumonitis," Military Medicine, Vol. 157, 1992, pg. 452-462.

reaction in a cohort of hospital personnel stationed at Al Eskan village near Riyadh, Saudi Arabia, from January to March 1991. They further postulated that in some cases, pathogens believed to originate in pigeon droppings might have further complicated the condition. The authors contend that in combination, this mixture contributed to an opportunistic lung infection in US military personnel so exposed.

2. Soot

The Thomas report describes soot as a combination of particles impregnated with tar and formed by the incomplete combustion of a carbon based material.[44] The Thomas report uses carbon black as a surrogate for soot because human health effects data and established occupational exposure standards are available for carbon black, and because the USAEHA data from the Gulf War shows the soot to be a well-combusted, carbon-based material similar in properties to commercial carbon black.[45] Respirable carbon black does not promote pulmonary fibrosis, as does silica. When inhaled by laboratory animals it produces little or none of the collagen produced fibroids seen in individuals suffering from silicosis.[46] Health effects from carbon black include reduced pulmonary function and irritation of the respiratory tract. These symptoms occur at high concentrations of carbon black over extended periods of exposure.[47]

VI. A REVIEW OF THE THOMAS REPORT

A. Summary

Thomas, et al (2000) has completed a peer-reviewed study on Gulf War veteran exposure to particulate matter. The heart of the study is an exposure assessment that examines particulate matter concentrations, specifically the silica and soot fractions, to which US personnel were exposed during the Gulf War. Based on available air quality data and US personnel unit location information, estimates were made of total exposure to particulate matter and compared to widely accepted US exposure guidelines. Such a comparison provides some sense of the potential health risks[48] faced by Gulf War veterans from exposure to particulate matter.

The main elements of the Thomas report are: 1) the data obtained during a comprehensive air quality monitoring study completed in 1991 by USAEHA (see Section III); 2) a scientific review of the literature on the environmental and occupational health effects of exposure to particulate matter; and 3) a standard methodology to assess the effect of exposure to particulates.

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[44] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War," May 2000, p. 22.
[45] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War," May 2000, p. 23.
[46] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War," May 2000, p. 25.
[47] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War," May 2000, p. 25.
[48] Risk is a relative term that describes the likelihood that an individual or population will develop a short- or long-term health effect from exposure to hazardous or toxic substances.

Information on the physical properties of particulate matter and its sources is also discussed in the report.

The literature review searched existing major scientific databases; these included: the occupational and environmental health effects literature from the Occupational Safety and Health Administration (OSHA) and the US Environmental Protection Agency (EPA), National Institute for Occupational Safety and Health (NIOSH) reports on silica health effects, and the exposure and health effects studies conducted on Gulf War veterans by the Department of Defense. The review also included relevant exposure and health effects studies of human populations in the Middle East. In all, the review covered 154 articles related to particulate matter exposure. In addition to this review, the authors of the Thomas report also interviewed members of the US Army Center for Health Promotion and Preventive Medicine (USACHPPM), formerly known as USAEHA, and other groups which authored papers on, or had specific knowledge of, particulate matter exposure.

The exposure assessment uses a methodology described in the National Academy of Sciences (NAS) Report, "Human Exposure Assessment for Airborne Pollutants/Advances and Opportunities." This methodology is used by federal agencies like EPA and OSHA to develop total human exposure scenarios (24-hours a day, seven days a week). The methodology estimates the cumulative exposure to which an individual is exposed (measured in units of concentration versus time, i.e., milligrams per cubic meter times year) and the total dose that the individual accumulates over the period of exposure.

The total dose (discussed in section VI.B.2) is calculated by multiplying the cumulative exposure by the daily inhalation rate. The Thomas report uses an inhalation rate of 24 cubic meters per day.[49] This is slightly higher than the 20 cubic meters per day that is used in the literature;[50] but, as the authors indicate, adds a conservative level to the analyses due to several physical factors exhibited by US troops (i.e., higher metabolic rate, increased activity, and higher respiration rate).[51] The USACHPPM has developed an even more conservative inhalation rate value for use in their health risk assessment studies. In their technical guidance document, "Long-term Chemical Exposure Guidelines for Deployed Military Personnel,"[52] the CHPPM recommends an inhalation rate of 29.2 cubic meters per day when conducting exposure and health risk assessments involving US troops. This rate is based on studies conducted by the US Army Research Institute of Environmental Medicine (USARIEM).[53] In their report the USARIEM estimates the metabolic rate as an indicator of heat stress for various physical tasks routinely performed in a military environment, and provides information on the inhalation rates associated with each of these activities. The inhalation rate of 29.2 cubic meters per day is a function of the

[49] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War," May 2000, p.6.
[50] Klaassen C.D., J Doull, and M.O. Amdur, "Casarett and Doull's Toxicology – The Basic Science of Poisons, Fifth Edition." The McGraw-Hill Companies, Inc., 1996, Edition 5; p. 84.
[51] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War," May 2000, p. 6.
[52] US Army Center for Health Promotion and Preventive Medicine ; Technical Guide (Reference Document) 230B, "Long-term Chemical Exposure Guidelines for Deployed Military Personnel," February 2000.
[53] US Army Medical Research and Materiel Command, "Metabolic Cost of Military Physical Tasks in MOPP 0 and MOPP 4," US Army Research Institute of Environmental Medicine, Natick, Massachusetts, April 1995.

activities that are conducted (i.e., those that are considered to be 'routine' or representative) on a daily basis, the associated inhalation rate for each of these activities, and an estimate of the amount of time spent on each activity. The inhalation rate, therefore, is the weighted-average of the rates for the individual activities.[54] The impact of this higher inhalation rate is discussed below.

B. Discussion

The Thomas report focuses on two types of exposure to assess the potential long-term or chronic effects from the inhalation of particulate matter. These are the *cumulative exposure* and *total dose*. It is necessary to consider both types of exposure when characterizing the potential chronic effects from silica and soot exposure.

1. Cumulative Exposure

This is a measure of the amount of a contaminant to which an individual is exposed over a specified time period. Its value is calculated by multiplying the measured concentration (expressed in milligrams per cubic meter) of the contaminant in the ambient air by the length of time (expressed in fractions of a year) that an individual was exposed to that concentration. Cumulative exposure is significant because it provides an indication of when the level of a contaminant in the air may approach levels of concern when compared to an established air quality standard. The standards for comparison used in the Thomas report are 1 mg/m^3 x year for silica and 87.5 mg/m^3 x year for soot. These are the levels below which there are no observed adverse health effects (NOAEL). The levels are calculated based on the results of human and animal studies. For example, the Thomas report notes that the risk of chronic health effects from silica exposure over a 5 to 45 year time frame begins to occur at cumulative exposure levels above 1 mg/m^3 x year.[55]

Contaminant concentration levels were determined based on monitoring results obtained during the USAEHA monitoring at seven locations in Kuwait and Saudi Arabia. The maximum-recorded values at each of these locations were multiplied by an occupationally derived time equivalent of 1.76 years[56] to obtain a worst-case *cumulative exposure* estimate at each of the seven locations. When compared against the *cumulative exposure* NOAEL, the estimated *cumulative exposures* for silica at the seven monitoring locations were between $1/50^{th}$ to $1/10^{th}$ of the respirable silica acceptable *cumulative exposure* NOAEL. When compared against the *cumulative exposure* NOAEL for soot the estimated *cumulative exposures* for soot at the seven

[54] In estimating the inhalation rate, deployed personnel were assumed to spend 6 hours sleeping (at an inhalation rate of 0.4 m^3/hr), 4 hours for sedentary activities (at 0.5 m^3/hr), 6 hours for light duties (at 1.2 m^3/hr), and 8 hours for moderate duties (at 2.2 m^3/hr). Therefore: (0.4 m^3/hr x 6hrs) + (0.5 m^3/hr x 4hrs) + (1.2 m^3/hr x 6hrs) + (2.2 m^3/hr x 8hrs) = 29.2 m^3/24-hour day.

[55] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War," May 2000, p. 7.

[56] A value of 1.76 years was derived to enable comparison between Gulf War personnel exposures and researched occupational levels. The average deployment to the Kuwait Theater of Operation (KTO) was for 153 days. This equates to a 1.76 year occupational equivalent when considering personnel were exposed 24 hrs/day or 168 hrs/wk, e.g., [168 hrs/wk]/[40 hrs/wk] x [153 days]/[365 days/yr] = 1.76 years. This formula assumes occupational exposures are 365 days per year, 52 weeks per year which adds an additional level of conservatism since OSHA considers occupational exposures to be 250 days per year, 46 weeks per year.

monitoring locations ranged between about 1/1000th to 1/250th the respirable soot acceptable *cumulative exposure* NOAEL.[57] The specific cumulative exposure estimates for silica and soot and their respective standards are presented in Table 2. Since the estimated cumulative exposure levels for silica and soot are well below their respective NOAEL, it is unlikely that the concentrations to which US personnel were exposed while in the KTO would result in the onset of adverse health effects.

2. Total Dose

This is a measure of the amount of respirable matter that is actually absorbed by the body. The *total dose* for inhaled respirable particulates is estimated by multiplying the *cumulative exposure* value by an inhalation rate of 24 cubic meters per day. Therefore, the NOAEL for *total dose* is obtained by multiplying the *cumulative exposure* NOAEL for silica and soot by the inhalation rate of 24 cubic meters per day. At total doses below this level one would not expect to see increased chances for the onset of disease from the intake of respirable contaminants. The estimated *total dose* for silica and soot at each of the seven monitoring locations was about 1/60th to about 1/14th the *total dose* NOAEL for silica and 1/4000th to about 1/1000th the total dose NOAEL for soot.[58] In other words the maximum total dose of silica and soot received by US personnel is significantly less than the level at which one would expect to see the onset of adverse health effects. These values and their relationship to the applicable NOAEL are also presented in Table 2.

If an inhalation rate of 29.2 cubic meters per day were used as suggested by the CHPPM the total dose received by US troops would increase by about 22%. Table 2 presents the total doses for silica and soot based on an inhalation rate of 29.2 cubic meters per day for comparison against the acceptable total dose NOAEL. From the table it can be seen that even at the elevated inhalation rate the total doses for silica and soot remain significantly lower than the acceptable total dose NOAEL.

[57] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War", May 2000, p. 8, 26, and 27. [These exposures are based on upper confidence 95% level data and a respirable silica content of 6.5%.]

[58] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War", May 2000, p. 8, 26, and 27. [These dosages are based on upper confidence 95% level data and a respirable silica content of 6.5%.]

Table 2. Estimated Exposures vs. Health Standards

Contaminant	Estimated Cumulative Exposure	Acceptable Cumulative Exposure	Estimated Total Dose[59]		Acceptable Total Dose
			(assuming an inhalation rate of 24 cubic meters per day)	(assuming an inhalation rate of 29.2 cubic meters per day)	
Silica	0.02 to 0.10 mg/m^3	1 mg/m^3 x yrs	49 to 208 mg	60 to 254 mg	3,066 mg
Soot	0.08 to 0.35 mg/m^3	87.5 mg/m^3 x yrs	184 to 735 mg	224 to 897 mg	766,500 mg

Source: Thomas et al., 2000.

Note: the acceptable cumulative and total doses assumed exposure to respirable, crystalline silica. This is a conservative assumption as the estimated dose may be overestimated being based upon PM_{10} air samplers. Also, it is assumed that all silica is crystalline, but there was no data available to determine how much (if any) of the silica was in the more toxic form (which can cause silicosis, pulmonary fibrosis), as opposed to the more benign amorphous silica.

C. Findings

The Thomas report calculated the cumulative exposures and total dosages of respirable silica and soot and compared them to widely accepted US exposure guidelines. The guidelines are expressed as "no observed adverse effect levels" (NOAEL). That is, they represent the concentration below which no adverse effects have been observed during human and animal laboratory and clinical studies. The report concludes that the cumulative exposures and total dosages were below the guidelines established by the US EPA for the protection of human health; therefore, chronic health effects would not be expected to occur.[60] Reversible, short-term or acute effects may occur, to include runny nose; eye, nose, and throat irritation; cough; and shortness of breath. These acute symptoms are due mainly to the high particulate content of the inhaled air, rather than solely the silica content in the air.

The report also addressed dermal exposures to particulate matter. Silica dusts are associated with specific types of dermatitis or skin inflammation. The report notes, however, that these irritations are not expected to produce long-term adverse skin disorders; normally, longer exposure periods (typically greater than three years) are required to cause these symptoms.[61]

[59] The estimated doses are conservative in that it was assumed that all of the particulate matter (including silica and soot) collected by the PM_{10} air samplers was respirable, which may not necessarily be the case. Though the PM_{10} air samplers do collect respirable matter, they do so with a greater efficiency than an ideal respirable air sampler that mimics the human respiratory tract and also collect non-respirable particles that are small enough to penetrate into the tracheobronchial region yet are too large to enter the pulmonary region (alveolar region where gas exchange occurs).

[60] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War," May 2000, p. 33.

[61] Thomas, R.B., T. Vigerstad, J. Meagher, and C. McMullin, "Particulate Exposure During the Persian Gulf War," May 2000, p. 21.

VII. CONCLUSIONS

A review of the data developed as a result of sampling conducted immediately after the Gulf War indicates that particulate matter levels in the air were significantly high and that concentrations often exceeded the levels considered safe for the protection of human health. The data also indicate that there was a significant mass of particles in the PM_{10} size range. Particles in this size range have the potential for entering the thoracic region of the respiratory tract. Both of these factors suggest that some personnel with pre-existing respiratory problems may have experienced aggravated symptoms. For example, the inhalation of ambient levels of particulate matter could have resulted in several acute symptoms and could have aggravated asthmatic conditions in some personnel. A number of studies have been completed on the acute effects of particulate matter exposure. Typical symptoms experienced by US personnel were cold- or flu-like and included cough, runny nose, eye and throat irritation, and shortness of breath. These symptoms are generally short-term and reversible.

Although high levels of particulate matter were observed, these concentrations fell within a range consistent with background levels observed in Kuwait where the average level of PM_{10} is nearly 600 $\mu g/m^3$, the highest in the world. Average PM_{10} concentrations measured by the USAEHA during a nine-month period in 1991 ranged from 265 to over 670 $\mu g/m^3$. This range is about 2 to 5 times greater than the US standard of 150 $\mu g/m^3$. The chemical composition of the samples indicated that roughly 75% of the airborne particulate matter consisted of clays, primarily calcium and silica that originated from the sand indigenous to this part of the world. Another 10% to 23% were carbon (soot) that originated from a combination of sources including the oil fires and various industrial sources, and less than 10% came from miscellaneous sources.

Respiratory complaints experienced during the Gulf War were not solely the result of exposure to high particulate matter levels, however. The Navy Forward Laboratory found that respiratory infections observed during the Gulf War were caused by well-known, common viral and bacterial agents, and in many cases were aggravated by the crowded living conditions experienced by some US personnel.

Thomas et al (2000) examined the potential for adverse health effects from long-term exposure to silica and soot. It should be noted, however, that these concerns were based on occupational studies for which exposure and health hazard information exist and are probably not the same as those received by Gulf War veterans. When found at high concentrations in an occupational environment, and under conditions of extended exposure, the medical literature notes that these particles have been associated with changes in lung function, damage to lung tissue, and altered respiratory defense mechanisms (e.g., an impaired ability to naturally eject foreign matter via exhalation).

As discussed in Section V, the critical dose (i.e., the amount of a contaminant actually taken in by the body necessary to cause some adverse health effect) is as much a function of the length of time an individual was exposed as it is the actual concentration to which the person was exposed. [See the discussion on cumulative exposure and dose in Section VI.] Therefore, an exposure to a high concentration of a contaminant becomes problematic only when the duration of the exposure results in the individual receiving a significant dose over an extended period of time.

For example, while US personnel were exposed to high levels of particulate matter during the Gulf War, the duration of these exposures was generally short (as compared to occupational exposures which can occur over a working lifetime), and thus the doses received by US personnel were likely to have been small when compared to an occupational exposure of longer duration.

The Thomas report supports this position. The report notes that the estimated exposures and total dosages to silica and soot were below human health protection standards, and therefore, chronic health effects would not be expected to occur. That is, the results suggest that there is not a link between the exposures to silica and soot received in the KTO and the unexplained illnesses reported by some Gulf War veterans. Reversible, short-term or acute effects attributable to the high levels of particulate matter, however, may have occurred. These would include runny nose; eye, nose, and throat irritation; cough; and shortness of breath. These acute symptoms would be due primarily to the high particulate content, rather than solely to the silica or soot content of the air.

These conclusions are based on inhalation exposure scenarios involving individual contaminants of concern (i.e., silica or soot) and do not take into account the possible synergistic effect of other toxic compounds that may be present. Further research is required to develop an understanding of the dose-response mechanisms associated with these types of exposure.

Dermal exposures to particulate matter were also examined. Silica dusts have been associated with specific types of dermatitis or skin inflammation. The Thomas report notes that these irritations are not expected to produce long-term adverse skin disorders since longer exposure periods (typically greater than three years) are normally required before these symptoms begin to occur.

VIII. AREAS REQUIRING FURTHER INVESTIGATION OR RESEARCH

Detailed information about the physical, chemical, and biological properties of particles that might cause the adverse health effects as observed in some Gulf War veterans is limited. Information about the mechanisms of toxicity and the synergistic effect of multiple compounds present in association with particulate matter is also limited. In general, there is not a clear relationship between the individual toxic components of airborne particulate matter and adverse health symptoms or indicators, such as respiratory and cardiovascular ailments. Nor are there toxicological evidence suggesting plausible biological mechanisms to explain the toxic effects attributed to particulate matter in epidemiological studies, or to determine how the populations at risk are exposed to these components. The USACHPPM, however, continues its collaborative efforts with the NOAA/Air Resources Laboratory to reconstruct daily particulate matter levels for Operation Desert Shield/Storm Kuwait Theater of Operations. This effort will provide additional information on particulate matter exposure levels of the KTO in relation to daily troop unit locations.

It should also be noted that the limitations in the data and the need for additional research noted above are not unique to the Gulf War setting or population, rather, they apply more generally to our knowledge of particulate matter exposures.

IX. LESSONS LEARNED

The primary symptoms of infectious disease among Gulf War participants were generally mild acute diarrhea and some forms of respiratory distress, which was expected, based on experiences from previous US deployments. Because of the unavoidable crowding during rapid mobilization for war and the inevitable exposure to infectious disease pathogens—especially in tropical and developing countries—diarrhea and respiratory disease will remain a problem for US personnel until effective preventive measures are developed.

The US military should therefore continue to support an aggressive program of preventive medicine, which is guided during deployments by continuous disease surveillance and on-site laboratory analyses. In addition, the military should maintain an infectious diseases research program to develop new vaccines, improved medical treatments, and more accurate and rapid diagnostic tests.

TAB A – Acronyms, Abbreviations, and Glossary

This TAB provides a listing of acronyms found in this report. Additionally, the Glossary section provides definitions for selected technical terms that are not found in common usage.

Acronyms and Abbreviations

ACGIH ..... American Council of Government Industrial Hygienists
AED ..... Aerodynamic equivalent diameter
DNA ..... Deoxyribonucleic acid
DoD ..... Department of Defense
EPA ..... US Environmental Protection Agency
KTO ..... Kuwait theater of operations
MEDLINE ..... On-line database containing 3,600 medical journals on medicine and health fields
NAAQS ..... National Ambient Air Quality Standards
NAS ..... National Academy of Science
NIOSH ..... National Institute for Occupational Safety and Health
NOAEL ..... No observed adverse effect level
OSHA ..... Occupational Safety and Health Administration
PM_{10} ..... Particulate matter at or below 10 microns in aerodynamic equivalent diameter
TSP ..... Total suspended particulate
TOXLINE ..... On-line database that provides toxicological information from 16 separate sources
µm ..... Micron or $1{,}000{,}000^{th}$ of a meter
$\mu g/m^3$ ..... Microgram per cubic meter
USACHPPM ..... United States Army Center for Health Promotion and Preventive Medicine
USAEHA ..... US Army Environmental Hygiene Agency
USARIEM ..... US Army Research Institute of Environmental Medicine
USIAAT ..... US Interagency Air Quality Assessment Team
VOC ..... Volatile organic compounds

Glossary

Acute — Refers to a brief—but not chronic—health effect. Sometimes loosely used to mean severe. Refers also to a brief, intense, short-term exposure.

Aerodynamic Equivalent Diameter — The settling rate of suspended particles and their penetration into the respiratory tract is in accordance with the particle AED, an expression that accounts for the inertial and aerodynamic drag properties of particles. The AED is dependent upon the particle density, shape, and size. The particle AED is defined as the diameter of a smooth, unit density [ρ_o = 1 gram per cubic centimeter (g/cm^3)] sphere having the same terminal settling velocity as the actual particle. The use of the AED enables one to standardize particles of different shapes, smoothness, and densities for direct comparative purposes

Alpha-quartz — The most stable form of crystalline silica in the environment. The vast majority of natural crystalline is in the form of alpha-quartz.

Alveolar Macrophage — Mononuclear cells within the lung tissues that are largely scavengers, ingesting dead tissue and degenerated cells. Synonym: carrier cell, scavenger cell.

Ambient — Surrounding or encompassing—usually referring to the environment in which an organism or apparatus functions.

Asthma — A chronic disorder of the lungs characterized by wheezing, coughing, difficulty in breathing, and a suffocating feeling, usually caused by an allergy to ingested substances.

Biologic Reactivity — Refers to the interaction of a non-living material with living tissues and cells (e.g., the DNA-damaging activity of silica).

Chronic — Refers to a health-related state lasting a long time. Refers also to a prolonged or long-term exposure. Sometimes means low-intensity. The US National Center for Health Statistics defines a chronic condition as one lasting three months or longer.

95% Confidence Interval — The statistically determined, upper- and lower-bound with a 95% chance that a measurement will occur within these upper and lower values.

Crystalline Silica — (see Quartz)

Cumulative Exposure — The proximity and/or contact with the source of a disease agent which accumulates or piles up in such a manner that the effective transmission of the agent or the harmful effects of the agent may occur.

Cumulative (Total) Dose — The total amount of a material or agent to which an organism is exposed for a period of time.

DNA — The chemical molecule inside cells which carries biological information. DNA is a double stranded molecule held together by weak hydrogen bonds between complementary base pairs of nucleotides (Adenine and Thymine, and Guanine and Cytosine). This molecule carries genetic information from parent to offspring.

Inflammation — A fundamental pathologic process consisting of a dynamic complex of cytological and chemical reactions which occur in the affected blood vessels and adjacent tissues in response to an injury or abnormal stimulation caused by a physical, chemical, or biologic agent.

Macrophage	Mononuclear cells within the lung tissues that are largely (Alveolar) scavengers, ingesting dead tissue and degenerated cells.
NOAEL	No observed adverse effect level. A toxicological reference level to a dose, cumulative exposure level, or time weighted average— below which pathologic consequences from exposure are not expected.
Occupational	Arising from, or related to, the workplace.
PM_{10}	A thoracic air sampler for particulate matter that meets the performance criteria specified by the USEPA in 40 Code of Federal Regulations (CFR) Part 50.6 and 40 CFR Part 53. The performance criteria includes a collection efficiency of 100% for particles of 0 to 1μm aerodynamic equivalent diameter (AED), 89.3% of 4μm AED, 55.1% at 10μm AED, 50.9% at 10.5μm AED, 4.1% at 15μm AED, and 0% at 16μm AED. The performance criteria are such that this type of sampler is more like a thoracic air sampler rather than a respirable air sampler.
Particulate	Composed of separate tiny masses of material or particles.
Pneumonitis	Inflammation of the lungs.
Quartz	A form of hexagonal crystalline silica or silicon dioxide (SiO_2) occurring in abundance, most often in a colorless, transparent form, but also sometimes in colored varieties used in semi-precious stones. The principal constituent of ordinary sand.
Respirable	The portion of an aerosol that is capable of entering the gas exchange regions of the lungs if inhaled. By convention, a particle-size fraction of the total airborne dust with aerodynamic diameters less than approximately 10μm and having a 50% deposition efficiency for those particles with an aerodynamic diameter of approximately 4μm.
Risk	The probability that an undesirable outcome will occur. Risk in this context is defined in terms of the probability of a particular adverse effect occurring. It has the dimensions of frequency of incidence (e.g., 1 in 1,000,000) and is coupled to an exposure estimate. The actual risk statement may be made in the form of the probability of an outcome associate with a unit exposure. For example, there is a lifetime "risk" of 2.5 excess cancers in 10,000 from an exposure to 1 part per million of a chemical in community air breathed 24 hours per day, every day for 70 years.

Shamal winds — A strong, hot, dry persistent northwest wind that occurs in Kuwait most often in summer and frequently is accompanied by dust storms, especially in the southern part of the country.

Thoracic — That portion of the respiratory tract that includes the lungs, both the conducting airways (tracheobronchial region) and the pulmonary region (alveolar region where gas exchange occurs). Particles that penetrate into the thoracic region will deposit either in the tracheobronchial region or the pulmonary region, depending upon the particle AED and the collection efficiency of the respiratory tract for a given particle AED. If the thoracic size particles are small enough (about 10 μm AED or less), then they may penetrate into the pulmonary region with greater efficiency.

TSP — Total suspended particulate, referring to the entire range of ambient air matter that can be collected, from the sub-micron level up to 50 μm in aerodynamic diameter.

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Environmental Exposure Report

Chemical Agent Resistant Coating (CARC)

Final Report

July 27, 2000

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Environmental Exposure Report

Chemical Agent Resistant Coating (CARC)

Final Report

July 27, 2000

Many veterans of the Gulf War have expressed concern that their unexplained illnesses may result from their experiences in that war. In response to veterans' concerns, the Department of Defense established a task force in June 1995 to investigate those incidents and circumstances relating to possible causes. The Office of the Special Assistant to the Deputy Secretary of Defense for Gulf War Illnesses assumed responsibility for these investigations on November 12, 1996.

Environmental Exposure Reports are reports of what we know today about certain events of the 1990-1991 Gulf War. This particular environmental exposure report focuses on the use of chemical agent resistant coating (CARC). The purpose of this report is to discuss the CARC painting activities conducted in the Kuwait Theater of Operations, describe possible health effects associated with exposure to CARC, and present recommendations for improvements in policy about CARC application. The narrative was initially published on February 22, 2000. Since that time, the Office of the Special Assistant for Gulf War Illnesses received new information which indicates that some civilian painters from Anniston, Alabama have experienced some medical problems which they attribute to their use of CARC paint during the Gulf War. No other information which contradicts the material presented here was received, nor have any additional leads developed to change the narrative's assessments. Additionally, the Presidential Special Oversight Board reviewed the narrative and recommended that the Office of the Special Assistant republish it as final. For this reason, this is a final report. However, if you believe you have information which may change this case narrative, please contact my office by calling:

1-800-497-6261

Bernard Rostker
Special Assistant for Gulf War Illnesses
US Department of Defense
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I. SUMMARY

The Iraqi invasion of Kuwait on August 2, 1990, led to Operations Desert Shield and Desert Storm and the deployment of approximately 697,000 US military personnel to the Kuwait Theater of Operations (KTO). As part of the deployment, the United States shipped thousands of vehicles and other equipment to the Persian Gulf, primarily, to Saudi Arabia. While most of the equipment was fully operational, much of it retained the three-color "woodland camouflage" paint scheme designed for operations in the European Theater or other non-desert areas of operation. This "woodland cammo" pattern obviously stuck out in the barren desert environment, making it easier for enemy gunners or reconnaissance assets to locate and target the vehicles. Consequently, there was an urgent operational requirement to repaint some of the incoming equipment with tan-colored chemical agent resistant coating (CARC) to provide desert camouflage protection.

CARC is a polyurethane paint that provides superior durability, extends service life for military vehicles and equipment, provides surfaces with superior resistance to chemical warfare agent penetration, and greatly simplifies decontamination. Established DoD occupational safety and health guidance called for proper personal protective equipment, including respiratory equipment, to protect painters. Several compounds in CARC formulations, if taken into the body in sufficiently high concentrations, may cause short- and long-term health effects. The most notable of these compounds is hexamethylene diisocyanate (HDI), which hardens, or plasticizes, the paint. Exposure to high concentrations of aerosolized HDI during spray painting leads to immediate respiratory irritation and watery eyes. Long-term exposure can cause or aggravate respiratory problems, in particular, asthma. The use of personal protective equipment, such as respirators, coveralls, eye protection, gloves, and head coverings, can prevent or minimize exposures to HDI. The HDI in polyurethane paint does not present a hazard after the paint dries and cures, unless exposed to heat sufficient for thermal decomposition of the coating, such as welding.

Solvents used in CARC and paint thinners, as well as solvents used to clean equipment, can be hazardous via skin contact and breathing. Exposures to solvents can lead to dizziness, rashes, and nausea. However, the proper wear of personal protective equipment greatly decreases the risks associated with exposure to solvents.

The purpose of this report is to:

- Clarify the issue of who could have been exposed to the hazards of CARC in theater;
- Discuss the scenarios under which CARC exposures could have occurred in theater;
- Describe the health effects associated with exposure to CARC; and
- Present recommendations for improvements in the policy regarding CARC to improve future usage.

Beginning in September 1990, a small group of Department of the Army civilians from Anniston, Alabama established the first in-theater painting operation at the port of Ad Dammam, Saudi Arabia (referred to as the Anniston Ad Dammam site). This group, experienced in CARC

painting operations, arrived with their own personal protective equipment, including paint suits, gloves, boot covers, and air-purifying respirators. The 900th Maintenance Company, a National Guard unit from Alabama, assumed operation of this paint site in February 1991.

In addition, the Army Materiel Command established two major new CARC spray painting operations in-theater at the Saudi Arabian ports of Ad Dammam and Al Jubayl in December, 1990, to process the majority of the Army equipment arriving in theater. The 325th Maintenance Company, of the Florida Army National Guard, operated these sites. The members of the 325th Maintenance Company lacked training or experience in CARC spray paint operations and the necessary personal protective equipment. By the time the two main painting sites had ceased operations in February 1991, a total of over 8,500 vehicles and other equipment had been painted in theater.

In addition to the two major CARC painting sites manned by the 325th, a number of smaller CARC painting facilities were established throughout the theater. These smaller sites operated for shorter periods and generally used brush and roller painting application techniques, rather than spray painting.

In April 1991, before redeployment from the Kuwait Theater of Operations, the Army's VII Corps reestablished painting operations in Ad Dammam and Al Jubayl to return tan vehicles to their original woodland camouflage paint schemes. Initially, personnel from the 325th Maintenance Company staffed these operations, but were later replaced by members of the incoming VII Corps. Altogether, these sites processed over 8,000 vehicles and other equipment, painting them with woodland CARC before shipping them to Europe, the United States, or other destinations.

During the painting operations, some servicemembers in the 325th Maintenance Company began reporting health problems. Prompted by these complaints, health and safety inspectors visited the major CARC painting sites on several occasions throughout the period from December 1990 through June 1991. With few exceptions, the inspection reports cited weak overall command and control, serious deficiencies in the type and quantity of personal protective equipment available, and soldiers who had not received sufficient training and information regarding the potential hazards associated with CARC paint operations. The inspections also revealed that some soldiers exhibited symptoms consistent with exposure to CARC.

These inspections brought some positive changes. The quality and availability of the personal protective equipment improved, additional training was provided, and in some instances, paint operations were suspended until the safety deficiencies were corrected. Air-supplied respirators, replacement air hoses, air compressors, gloves, and eye protection, as well as explosion-resistant lighting and electrical outlets, became increasingly available. Nevertheless, some of this equipment did not arrive at the paint sites until months after the initiation of painting activities. Equipment failure and maintenance difficulties, as well as inconsistent adherence to proper health and safety procedures by painters and their chain-of-command, were some of the factors that led to the persistent problem of unsafe working conditions.

Following their deployment, some service members from the 325th Maintenance Company communicated their CARC painting experiences and concerns to their US representative, Charles Canady of Florida's 12th District. A series of correspondence between the congressman and DoD officials discussed the issues of CARC exposures and follow-on medical care for Operation Desert Storm National Guard members. The matter was referred to the National Guard Bureau for investigation. The National Guard Bureau Inspector General (IG) issued an assessment addressing health care issues for veterans of Operations Desert Shield and Desert Storm in June 1994.

A number of veterans of the 325th Maintenance Company have sought treatment or assistance from the military health system or the Department of Veterans Affairs health care for symptoms they believe to be linked to their Gulf War exposures. The Department of Veterans Affairs has linked the illnesses suffered by some of the members of the 325th to exposures to CARC. The process of evaluating and treating veterans of the 325th Maintenance Company continues to the present day.

Veterans have voiced concerns about health problems that they attribute to their exposure to CARC. The most frequently cited symptoms are: coughing, eye and throat irritation, skin rashes, headaches, nausea, and asthma—symptoms often indicative of adverse health effects resulting from exposures to the HDI in CARC and the solvents often used in the related mixing, spray application, and clean-up activities. In a number of cases, personnel who were directly involved in the major spray painting operations of CARC were diagnosed with respiratory ailments that could be attributed to exposure to CARC (although other, unknown causitive factors cannot be ruled out). However, this investigation cannot definitively link CARC paint to the undiagnosed illnesses reported by Gulf War veterans that were not engaged in painting operations.

The Office of the Special Assistant for Gulf War Illnesses developed three important findings from its investigation of CARC painting performed in the Gulf theater. These lessons and recommendations are summarized below.

- Some soldiers reported that a number of standard operating procedures, including painting vehicles with CARC, were modified in the rush to mobilize personnel and equipment for Operations Desert Shield and Desert Storm. In some cases, safety considerations were disregarded or otherwise compromised. In the future, military operational planning should incorporate measures to meet occupational safety and health standards even under "surge requirements". Prior planning should improve the military's ability to quickly establish austere, field-expedient, but safe CARC painting sites. Advance hazard awareness training and education would help prevent or minimize risky practices and needless exposures. In the future, the CARC-painting mission should be assigned to appropriate units before deployment—units that could rapidly obtain the required occupational and safety training and guidance, procure personal protective equipment, and plan for the assignment of direct, qualified oversight by trained, certified safety and occupational health professionals.

- Upon their return to the United States, members of the 325th Maintenance Company left active duty without completing post-deployment occupational health evaluations, missing the opportunity to identify and document many of the problems they encountered. To prevent the recurrence of this type of situation, the services (including the Reserve Component) need to ensure compliance with medical surveillance policies and procedures aimed at establishing both a baseline (pre-deployment) health status of individuals, and capturing any deployment-related exposures and health symptoms after their return from deployments.

- The redeployment painting operations conducted in-theater were better organized and more established than were the field-expedient operations initially established for tan painting. Nevertheless, routine safety inspections continued to document numerous problems. Occupational Safety and Health Administration (OSHA) regulations do not apply to combat operations. However, redeployment operations should strictly adhere to OSHA regulations. In addition, existing DoD guidance governing safety and occupational health issues in deployment settings were not observed in numerous cases.

Subsequent sections of this report will examine issues relevant to CARC painting and include:

- A description of CARC, including technical information, health and safety standards, and doctrine available prior to the Gulf War;
- An examination into the use of CARC during the Gulf War, including the locations and major units involved; and
- A discussion of the medical care for the 325th Maintenance Company following the Gulf War.

Tabs A and B contain an acronym and abbreviation listing, a glossary, and a bibliography. See Tabs C through E for a technical discussion of CARC specifications and formulations, examples of solvents used in painting operations, and a discussion of safety and health regulations, respectively. Tab F provides a brief summary of the changes in to the interim report.

II. METHODOLOGY

OSAGWI followed a five-step process in its investigation of the possible health risks related to the use of CARC. We limited our investigation to the major spray paint operations that were conducted in the Kuwait theater of operations.

A. Determine Chronology of Events

This investigation used the following methods to determine the chronology of events:

- Interviews of veterans who were directly involved with, or had knowledge of, in-theater CARC painting operations;
- A thorough review of operational logs, memoranda, reports, and journals from classified and unclassified databases;
- Interviews of health and safety professionals who were in theater.

B. Determine Proper Standards and Procedures

To compare actual CARC painting practices to established policies and procedures, investigators conducted interviews with health and safety personnel and reviewed technical guides, field manuals, training videocassettes, and Gulf War message traffic.

C. Review Technical Specifications

Investigators, in coordination with the Army Research Laboratory, the Army's lead agency on all paints and coatings, conducted a thorough review of technical specifications of CARC. Investigators placed emphasis on identifying any CARC compounds that could cause or contribute to adverse health effects.

D. Determine Possible Health Effects of Compounds of Concern

We reviewed medical literature to determine what health effects—acute and/or chronic—may be associated with CARC's chemical components.

E. Review Medical Follow-up

To obtain a clearer picture of the types and levels of care provided to soldiers involved in painting operations, investigators contacted military physicians and specialists working with the Department of Defense Comprehensive Clinical Evaluation Program (CCEP). These physicians and specialists conducted follow-up medical examinations on a number of soldiers involved with the painting operations. The Department of Veterans Affairs shared summarized information about the symptoms and diagnoses as reported for the 325th Maintenance Company.

III. DESCRIPTION OF CARC

A. What is CARC?

The US military relies on paint to achieve a variety of visual and mechanical effects, ranging from camouflage to unit identification to the protection of metal surfaces. CARC-painted surfaces resist the absorption of chemical warfare agents, making decontamination much easier to accomplish. Chemical agent resistant coatings—CARC—make up the largest category of paints applied to the US military's inventory of equipment. CARC's ability to conceal and protect improves the survivability of tracked and wheeled vehicles, artillery pieces and missile launchers, rotary and fixed-wing aircraft, and support equipment such as communications vans, water purification units, generators, and forklifts.

The Army developed the first chemical agent resistant coatings in 1974. The Army made the decision in 1983 to require all combat, combat support, tactical wheeled vehicles, aircraft, and essential ground support equipment (i.e., tactical equipment) be painted with CARC.[1] This decision initiated the development of the CARC protocol as it exists today. As a result of stringent health and environmental regulations, lead and hexavalent chromium were removed from CARC and the levels of solvents or volatile organic compounds (VOCs) were reduced. These actions occurred before the Gulf War.[2]

CARC is essentially a low gloss version of automotive-grade polyurethane paint. These coatings provide the standard characteristics of any protective finish: corrosion resistance, durability, identification marking, etc. However, CARC formulations provide some unique properties that distinguish them from typical commercially-available paints.

Chemical agent resistant coatings all have a very matte finish, or extremely low gloss, to minimize visual detection due to glare or reflection from the sun or other bright light sources.

Because chemical warfare agents are unable to penetrate the coating, a standard military decontaminating solution, such as decontaminating solution number two (DS2), can readily neutralize surface chemical contaminants on CARC-painted vehicles. [3] CARC's resistance to a variety of chemicals and solvents, and its ability to withstand weathering—including exposure to sunlight—has made CARC the paint of choice for outdoor use in a military-operational environment.

While all colors of CARC are chemically similar, the pigmentation additives in CARC formulations have unique properties and characteristics that make them particularly suitable for military operations. For example, the base green color—referred to as Green 383—used in the common three-color woodland pattern employed throughout the military, uses two types of pigments with reflectance properties in the near-infrared region of the spectrum. The

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[1] Headquarters, Department of Army message, Subject: "Army Adoption of Chemical Agent Resistant Coating (CARC)," May 6, 1983.

[2] Lead Sheet #15187, Interview with Army Research Laboratory research chemist, February 25, 1998, p 1-2.

[3] Lead Sheet #15187, Interview with Army Research Laboratory research chemist, August 9, 1999, p. 3.

combination of these pigments mimics the reflectance properties of chlorophyll present in living foliage, such as tree leaves and grasses, and thus minimizes detection of woodland-scheme CARC-painted equipment by near-infrared detectors. Another color, Tan 686, was reformulated with higher reflectance pigmentation to reduce the amount of solar heat vehicles would absorb, which was a serious concern during Operation Desert Shield. A subsequent color change, designated Tan 686A, increased the reflectance properties of the coating. Initial supplies of CARC available in the early stages of Operation Desert Shield were Tan 686. As new batches of CARC were manufactured to meet the supply needs, Tan 686A became the standard.[4] See Tab C for a discussion of CARC formulations.

B. Technical Specifications

All color variations of CARC must meet stringent military specifications. The typical formulation of these finishes consists of three primary groups of raw materials: the resin or binder system, the pigment package, and the solvents.

As a means of standardizing the paint formulations manufactured by various suppliers, the military uses a system of military specifications (MIL SPEC). The military specification lists all the requirements of the paint, including composition, color and spectral reflectance properties, and label markings. In addition, the military maintains a list of approved suppliers called the qualified products list (QPL) as another control measure to ensure the consistency, quality, and performance of its paints. The military procures CARC only from suppliers on the qualified products list. The Army Research Laboratory has rigorously tested the products of the manufacturers listed on the QPL for conformance to all specifications of performance and composition.[5] See Tab C for a detailed discussion of the military specifications and qualified products list for CARC.

C. Health Considerations

1. Identification of Compounds of Concern

Because polyurethane paint has been commercially available for years, documentation exists about the hazards and toxicity of this category of paints. While it is well known that the isocyanates found in polyurethane paints pose the most significant health risks, solvents in the paints, thinners, and cleaning products are also known to pose a secondary health risk, if absorbed in sufficient quantity.[6]

Most of the components of CARC are not unique; almost any polyurethane paint contains them. Hexamethylene diisocyanate (HDI) is the only isocyanate found in CARC.[7] Inhalation of

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[4] Lead Sheet #15187, Interview with Army Research Laboratory research chemist, August 9, 1999, p. 3.
[5] Lead Sheet #15187, Interview with Army Research Laboratory research chemist, August 9, 1999, p. 4.
[6] US Army Environmental Hygiene Agency, "Guidelines for Controlling Health Hazards in Painting Operations," Technical Guide 144, August 24, 1987, p. 2-3, 2-5, 3-1, 5-1, 7-1.
[7] US Army Environmental Hygiene Agency, "Guidelines for Controlling Health Hazards in Painting Operations," Technical Guide 144, August 24, 1987, p. 5-1.

airborne droplets containing HDI released during spray paint applications is a well-documented hazard.[8] Direct skin contact to wet CARC is another avenue of exposure that causes irritation of the skin and mucus membranes, and possible absorption of solvents.[9]

Dry CARC poses no known health threat unless disturbed by sanding, grinding, extreme heat, or other conditions that could produce CARC dust, fumes, or vapors. Welding or cutting CARC painted surfaces results in the airborne release of HDI, carbon monoxide, and other toxic materials.[10]

Solvent exposure may occur as a result of contact with any solvent-based paint, including CARC, due to the high volatility (the ability to vaporize readily) of most solvents. Solvent exposure can occur during the surface preparation phase, however, in the Kuwait Theater of Operations, minimal surface preparation occurred.[11]

Solvents are released from CARC during the drying and curing process. These solvents are readily absorbed through the skin and through the respiratory tract.[12,13] Thinners are often added to the paint solution to achieve the correct spray paint viscosity. As the thinners evaporate, excessive solvent concentrations may occur, especially in areas with minimal airflow or ventilation.[14]

Exposure to solvents also occurred during the Gulf War when a variety of solvents were used to clean painting equipment and tools. Some of the solvents used for this purpose were locally procured, and therefore, the identity of all the solvents used in theater is not known.[15]

Tab D presents a listing of the solvents found in some of the paints and thinners most likely used during the CARC painting operations in the Gulf theater. This tab includes information on permissible exposure limits, lower explosive (flammable) limits in air (LEL), concentrations which are immediately dangerous to life or health (IDLH), odor characteristics, health effects, and target organs.

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[8] Memorandum for All Medical Facility/SGPB from Detachment 1, HSC/OEMI, Subject: "Consultative Letter, AL-OE-BR-CL-1998-0105, 1,6-Hexamethylene Diisocyanate Exposures During Polyurethane Spay Painting Operations," August 28, 1999, p. 1-2.

[9] US Army Environmental Hygiene Agency, "Guidelines for Controlling Health Hazards in Painting Operations," Technical Guide 144, August 24, 1987, p. 7-1.

[10] US Army Environmental Hygiene Agency, "Guidelines for Controlling Health Hazards in Painting Operations," Technical Guide 144, August 24, 1987, p. 2-4.

[11] Lead Sheet #14228, Interview with 325th Maintenance Company painter, January 21, 1998, p. 2.; Lead Sheet #14237, Interview with 3rd Armored Calvery Regiment painter, January 22, 1998, p.1; Lead Sheet #14254, Interview with 325th Maintenance Company painter, January 26, 1998, p. 2; Lead Sheet #14369, Interview with CARC paint site inspector, February 6, 1998, p. 1; Lead Sheet #14978, Interview with 325th Maintenance Company painter February 10, 1998, p. 1.

[12] Gerr, F. and R. Letz, "Organic Solvents," Environmental and Occupational Medicine, 1998, p. 1094-1095.

[13] Memorandum from US Army Environmental Hygiene Agency for Headquarters, Department of Army, Subject: "Health Effects Anticipated Following Occupational Exposure to Chemical Agent Resistant Coating (CARC) Paint," August 23, 1993, p. 2.

[14] US Army Environmental Hygiene Agency, "Guidelines for Controlling Health Hazards in Painting Operations," Technical Guide 144, August 24, 1987, p. 2-1.

[15] Lead Sheet #20618, Interview with 22nd Support Command safety officer, December 8, 1998, p. 3.

2. Possible Health Effects of Hexamethylene Diisocyanate and Solvents

Exposure to isocyanates and solvents without proper protection can be harmful. Isocyanate exposure, including exposure to the HDI found in CARC, can cause three types of health effects:

- Almost all persons exposed to relatively high concentrations of isocyanates will develop irritation to skin and the respiratory tract;
- A small proportion of persons who are chronically exposed can become sensitized and develop asthma;
- A small proportion of persons who are chronically exposed can develop hypersensitivity pneumonitis.

At high concentrations, isocyanates can cause non-specific irritation of the mucous membranes and respiratory tract in some individuals, even after relatively short-term (minutes to hours) exposures.[16] At high concentrations, HDI causes shortness of breath, chest pain, chest tightness and cough and is extremely irritating to the eyes, nose, and throat, causing watery eyes and burning sensations.[17,18] At high enough concentrations, nearly all exposed persons will exhibit some or all of these short-term symptoms, but when the exposure stops, the symptoms will generally resolve rapidly.[19]

A small proportion of individuals exposed to HDI over a period of months to years may develop asthma.[20] This occurs sometimes even at relatively low concentrations over time.[21] Sensitization to isocyanates after exposures of shorter duration (days or weeks) is unlikely.[22,23,24] However, once a person is sensitized to isocyanates, an exposure to levels as low as the parts-per-billion range can cause the onset of episodes of wheezing, shortness of breath, chest tightness, and coughing.[25,26,27] Sensitized persons may suffer progressive worsening of respiratory symptoms

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[16] Memorandum from US Army Environmental Hygiene Agency for Headquarters, Department of Army, Subject: "Health Effects Anticipated Following Occupational Exposure to Chemical Agent Resistant Coating (CARC) Paint," August 23, 1993, p. 2.

[17] Memorandum from US Army Environmental Hygiene Agency for Headquarters, Department of Army, Subject: "Health Effects Anticipated Following Occupational Exposure to Chemical Agent Resistant Coating (CARC) Paint," August 23, 1993, p. 2.

[18] US Environmental Protection Agency, Technology Transfer Network, Hexamethylene-1-6-Diisocyanate, web site www.epa.gov/ttn/uatw/hlthe/hexa-dii.html (as of December 14, 1998).

[19] Memorandum from US Army Environmental Hygiene Agency for Headquarters, Department of Army, Subject: "Health Effects Anticipated Following Occupational Exposure to Chemical Agent Resistant Coating (CARC) Paint," August 23, 1993, p. 2.

[20] Banks, D.E., "Respiratory Effects of Isocyanates," Environmental and Occupational Medicine, 1998, p. 542.

[21] Banks, D.E., "Respiratory Effects of Isocyanates," Environmental and Occupational Medicine, 1998, p. 541-542.

[22] Banks, D.E., "Respiratory Effects of Isocyanates," Environmental and Occupational Medicine, 1998, p. 542.

[23] Memorandum from US Army Environmental Hygiene Agency for Headquarters, Department of Army, Subject: "Health Effects Anticipated Following Occupational Exposure to Chemical Agent Resistant Coating (CARC) Paint," August 23, 1993, p. 2.

[24] Bernstein, D.I., "Allergic Reactions to Workplace Allergens," *Journal of American Medical Association*, December 10, 1997, p. 1907-1913.

[25] Banks, D.E., "Respiratory Effects of Isocyanates," Environmental and Occupational Medicine, 1998, p. 540-542.

with recurrent exposures.[28] When exposures stop, the asthma may resolve; on the other hand, it may be persistent and may be triggered by other factors, such as tobacco smoke, cold air, or exercise.[29,30] The general, worldwide population diagnosed with asthma ranges from 5 to 10%.[31]

Hypersensitivity pneumonitis, though uncommon, is another known effect of chronic exposure to isocyanates. The symptoms of hypersensitivity pneumonitis can be severe, and, in most cases, abnormalities will appear on chest X-ray and pulmonary function tests. Symptoms, which usually occur about three to eight hours after exposure, include repeated bouts of fever, muscle aches, headaches, malaise, shortness of breath, dry cough, and chest tightness. Removal from exposure is usually mandatory. Sometimes the condition persists, even when no longer exposed to isocyanates. In such cases, medications such as steroids may be necessary.[32,33,34]

Some solvents found in CARC are readily absorbed through the respiratory tract and skin.[35,36] Exposure to high concentrations of solvents can lead to non-specific central nervous system effects, ranging from headaches or dizziness, to more serious effects, including staggering gait, nausea, vomiting, or loss of consciousness.[37,38] At high levels, solvent vapors can also cause irritation of the eyes, skin, mucous membranes, and respiratory tract. If exposures are brief (for example, an eight-hour shift), these irritant and central nervous system effects are generally transient and resolve rapidly after cessation of exposure.[39,40] Nevertheless, chronic, long-term exposure to solvents can cause skin rashes, usually leading to an irritant dermatitis, characterized by dryness, scaling, and cracking of the skin, especially of the hands.[41]

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[26] Chan-Yeung, M. and J.L. Malo, "Occupational Asthma," *The New England Journal of Medicine*, July 13, 1995, Volume 333, No. 2, p. 107-112.
[27] "Preventing Asthma and Death from Diisocyanate Exposure," DHHS (NIOSH) publication no. 96-111, 1996, we site www.cdc.gov/niosh/asthma.html (as of November 12, 1999).
[28] Banks, D.E., "Respiratory Effects of Isocyanates," Environmental and Occupational Medicine, 1998, p. 540-542.
[29] Banks, D.E., "Respiratory Effects of Isocyanates," Environmental and Occupational Medicine, 1998, p. 541-542.
[30] Chan-Yeung, M. and J.L. Malo, "Occupational Asthma," *The New England Journal of Medicine*, July 13, 1995, Volume 333, No. 2, p. 107-112.
[31] Chan-Yeung, M. and J.L. Malo, "Occupational Asthma," *The New England Journal of Medicine*, July 13, 1995, Volume 333, No. 2, p. 107-112.
[32] Banks, D.E., "Respiratory Effects of Isocyanates," Environmental and Occupational Medicine, 1998, p. 547-548.
[33] "Preventing Asthma and Death from Diisocyanate Exposure," DHHS (NIOSH) publication no. 96-111, 1996, web site www.cdc.gov/niosh/asthma.html (as of November 12, 1999).
[34] Cormier, Y., "Hypersensitivity Pneumonitis," Environmental and Occupational Medicine, 1998, p. 457-465.
[35] Gerr, F and R. Letz, "Organic Solvents," Environmental and Occupational Medicine, 1998, p. 1094.
[36] Memorandum from US Army Environmental Hygiene Agency for Headquarters, Department of Army, Subject: "Health Effects Anticipated Following Occupational Exposure to Chemical Agent Resistant Coating (CARC) Paint," August 23, 1993, p. 2-3.
[37] Gerr, F. and R. Letz, "Organic Solvents," Environmental and Occupational Medicine, 1998, p. 1091, 1096.
[38] Memorandum from US Army Environmental Hygiene Agency for Headquarters, Department of Army, Subject: "Health Effects Anticipated Following Occupational Exposure to Chemical Agent Resistant Coating (CARC) Paint," August 23, 1993, p. 3-4.
[39] Gerr, F. and R. Letz, "Organic Solvents," Environmental and Occupational Medicine, 1998, p. 1096.
[40] Memorandum from US Army Environmental Hygiene Agency for Headquarters, Department of Army, Subject: "Health Effects Anticipated Following Occupational Exposure to Chemical Agent Resistant Coating (CARC) Paint," August 23, 1993, p. 3.
[41] Gerr, F. and R. Letz, "Organic Solvents," Environmental and Occupational Medicine, 1998, p. 1091, 1094.

Long-term exposure to solvents has been associated with increased rates of chronic central nervous system symptoms, such as fatigue, irritability, depression, headaches, poor concentration, and forgetfulness.[42] These chronic effects generally occur only after several years of heavy exposure (many experts estimate a threshold to be about ten years of relatively heavy exposure).[43] Some solvents can cause peripheral neuropathy, which means damage to the nerves in the arms and legs.[44] CARC does not contain the solvent compounds that are most closely associated with this type of nerve damage.

Workers occasionally develop liver or kidney disease after either long-term exposure or a massive single over-exposure to some solvents. Generally, chlorinated solvents cause these effects. CARC does not contain chlorinated solvents. A few solvents, such as benzene, are known or suspected to be human or animal carcinogens (cancer-causing agents),[45] but CARC has been specifically formulated to eliminate these types of solvents.

D. Occupational Safety and Health Guidance

Tab E provides a detailed discussion of safety and health requirements for CARC painting operations, including Occupational Safety and Health Administration (OSHA) and National Institute of Occupational Safety and Health (NIOSH) requirements, as well as military guidance for conducting CARC paint operations. The tab also includes a discussion of material safety data sheets and the hazard communication program. A direct comparison of the exposures during the Gulf War to existing standards is theoretical since no workplace sampling or measurements were taken during the war. These standards are discussed in detail in Tab E and in the applicable cited references, but the most important aspect of this discussion is that there were no measurements taken during the Gulf War for direct comparison. Obviously, this has hampered retrospective efforts to evaluate the frequency, intensity, and duration of exposures, and their subsequent medical or health effects.

Nevertheless, two conclusions can be drawn. First, current Army and federal occupational and safety directives require the use of personal protective equipment, including respiratory protection, during polyurethane (CARC) spray painting operations. Second, based on experience and professional judgment of the health and safety professionals monitoring the CARC painting operations in-theater, unprotected personnel who were spray painting CARC in the conditions documented in the Gulf were exposed to potentially hazardous conditions.

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[42] Gerr, F. and R. Letz, "Organic Solvents," Environmental and Occupational Medicine, 1998, p. 1097.
[43] Gerr, F. and R. Letz, "Organic Solvents," Environmental and Occupational Medicine, 1998, p. 1098.
[44] Gerr, F. and R. Letz, "Organic Solvents," Environmental and Occupational Medicine, 1998, p. 1095.
[45] Gerr, F. and R. Letz, "Organic Solvents," Environmental and Occupational Medicine, 1998, p. 1102.

IV. USE OF CARC DURING OPERATIONS DESERT SHIELD AND DESERT STORM

A. Overview

The commitment of US forces to the Kuwait Theater of Operations in support of Operations Desert Shield/Desert Storm (ODS/DS) required the rapid, large-scale deployment and build-up of troops and equipment to Southwest Asia from the continental United States and Europe. Because much of this equipment, particularly from the US Army's Germany-based VII Corps, arrived in-theater painted in woodland camouflage colors, Central Command directed that units repaint their equipment with tan CARC to enhance troop and equipment survivability. The US Army XVIII Airborne Corps painted a significant portion of its combat vehicles tan prior to deployment. For this reason, CARC painting in the Kuwait theater of operations focused mostly on the VII Corps vehicles.

From the early planning stages, the US military anticipated that only a limited number of vehicles would be painted with tan CARC. There were three primary constraints: 1) the urgent massing of combat power in tactical assembly areas could not be slowed by painting operations; 2) the existing paint-application capability of the Army Materiel Command (AMC) could not be expanded to paint every vehicle in theater; and 3) the existing supplies of CARC were limited. VII Corps established painting priority to combat vehicles (i.e., Abrams tanks, Bradley Fighting Vehicles, and engineer breaching equipment), as well as to command and control vehicles (i.e., M577 tracked command vehicles and M113 armored personnel carriers).[46]

The shortage of CARC was a key issue of concern. VII Corps considered two options. The first option was to paint as many of the lead or first vehicles in theater as possible, and hope that additional CARC would become available for later-arriving units. The second option was to paint only priority vehicles from lead units and save enough CARC to paint the priority vehicles of units arriving later. If more CARC than anticipated arrived, CARC would be sent to the tactical assembly areas to paint lower priority vehicles that had already passed through the port. VII Corps selected the second option.[47,48]

The port support authority and the port assistance task force (TF), TF North, assisted the Army Materiel Command and the 325th Maintenance Company as they established the paint site in Al Jubayl. They informed units of the process to prepare and paint vehicles, and they coordinated support provided to the civilian and military painters.[49]

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[46] Annex B (Port Operations) to 1st ID(F) Operation Desert Shield/Storm AAR Background Papers, p. B-11.
[47] Annex B (Port Operations) to 1st ID(F) Operation Desert Shield/Storm AAR Background Papers, p. B-12.
[48] Lead Sheet #15359, Interview with 593rd Area Support Group commanding officer, March 6, 1998, p. 1.
[49] Annex B (Port Operations) to 1st ID(F) Operation Desert Shield/Storm AAR Background Papers, p. B-12.

The increasing supply of CARC to the theater eventually allowed almost all tracked vehicles on the list of priority vehicles to be painted. Eventually units were given the latitude to allocate CARC to other vehicles.[50]

By the time large-scale painting at the port ceased in February, the original mission given by the VII Corps commander had been achieved—3,500 priority vehicles painted—without slowing the movement of units into tactical assembly areas. In addition, 5,000 other vehicles were painted.

The port support authority sent 4,700 gallons of paint to the tactical assembly areas to paint additional vehicles. Army Materiel Command provided technical experts to short-term paint sites in the tactical assembly areas, including sites in the 1st Armored Division sector and one in the 3rd Armored Division sector.[51] The VII Corps Artillery, the 7th Engineer Brigade, and Detachment 1 of the 101st Military Intelligence Battalion, as well as the 207th Military Intelligence Brigade and 14th Military Police Brigade, were also provided with equipment and supplies to finish their priority vehicles in their tactical assembly areas. Brushes, rollers, and safety masks were purchased locally by the port support authority.[52] Table 1 shows the number of VII Corps vehicles, by unit, that were painted with tan CARC as of February 14, 1991.[53]

Table 1. CARC painting tally as of February 14, 1991

Unit	Tracked Vehicles Painted	Wheeled Vehicles Painted	Total Painted
1st Armored Division	1415	475	1890
2nd Armored Division (Forward)	442	658	1100
3rd Armored Division	1699	995	2694
Corps Artillery	314	62	376
7th Engineer Brigade	462	698	1160
2nd Armored Cavalry Regiment	398	1011	1409
TOTAL	**4730**	**3899**	**8629**

B. Painting Protocol During Operations Desert Shield and Desert Storm

Before Operation Desert Shield began, a well-established set of regulatory guidance existed detailing the procedures for vehicle painting and safety and occupational health requirements. Army technical manuals of that period required that CARC be applied to all combat, combat support, and combat service support equipment. To assure the most effective CARC protection, approved directions for surface preparation involved the following steps: 1) remove loose paint by light sandblasting; 2) wash cleaned areas with a specified liquid detergent cleanser; 3) allow surface to thoroughly dry; and 4) clean surface with solvent within four hours of detergent

[50] Annex B (Port Operations) to 1st ID(F) Operation Desert Shield/Storm AAR Background Papers, p. B-12, B-13.
[51] Annex B (Port Operations) to 1st ID(F) Operation Desert Shield/Storm AAR Background Papers, p. B-13.
[52] Annex B (Port Operations) to 1st ID(F) Operation Desert Shield/Storm AAR Background Papers, p. B-13.
[53] "VII Corps CARC Paint Operation," Appendix 19 to Annex A to 1st ID (F) Operation Desert Shield/Storm AAR of VII Corps Debarkation and Onward Movement, p. A-19-1.

wash.[54] However, this protocol was not followed during the Gulf War. Instead, vehicles received minimal surface preparation and CARC was applied to the existing coating.

Significant additional pre-war guidance existed in Army Technical Manual 43-0139, "Painting Instructions for Army Materiel." This includes descriptions and warnings of undercoats, finish materials, and related materials, drawings of proper paint patterns, vehicle inspection procedures, and descriptions of painting equipment.[55]

A number of command directives were issued dictating procedures for vehicle painting. Unit maintenance managers at all levels were periodically informed of the changing priorities and policies. As an example, a point paper written in the early stages of the US deployment listed several major potential hazards to avoid. Among them was the failure to properly follow established safety procedures when painting with CARC.[56]

A notable portion of the policy disseminated during Operations Desert Shield/Storm related to small scale, unit-level painting. This type of painting was limited to touchup, or spot-painting, using brushes or rollers. Policy dictated the use of at least half-face respirators with organic vapor cartridges, but medical surveillance during the operation was waived unless the painting operation exceeded 30 days. However, the wearers of respirators were to be fit-tested and medically cleared prior to beginning work. Spray painting, sand blasting, and power sanding was to be limited to large-scale maintenance operations. Policy also required workers and supervisors to review material safety data sheets before spot painting. The policy prohibited the use of solvents for surface preparation prior to spot painting.[57]

References to painting procedures at the division maintenance level is found in Gulf War military message traffic. Within VII Corps, tanks, Bradley fighting vehicles, command and control vehicles (e.g., M577s and M113s), engineer breaching vehicles, fire support team vehicles (FSTV), and high mobility multi-wheeled vehicles (HMMWV) received priority at division maintenance spray sites. The unit owning the vehicles controlled the flow of the vehicles into the paint site,[58] not the unit painting the vehicles. Command guidance from Army Materiel Command explains that spray painting was only to be conducted in large maintenance areas to meet OSHA regulations, while unit level repainting was to be limited to brushes and rollers.[59]

In addition to the painting procedures applicable for painting ground vehicles, there was also a limited amount of instruction as to the proper way to paint Army aircraft. The high reflective desert-blending paint schemes for ground vehicles made aircraft three times more vulnerable to

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[54] "Painting Instructions for Army Materiel," US Army Technical Manual (TM) 43-0139, July 27, 1988, p. 3-1.
[55] "Painting Instructions for Army Materiel," US Army Technical Manual (TM) 43-0139, July 27, 1988.
[56] MG Dyer, Travis N., Point Paper from United States Army Director of Personnel, "Issue: Safety During Desert Shield Mobilization," November 19, 1990.
[57] CINCUSAREUR message, Subject: "CARC Touch-up/Spot Painting Policy," October 15, 1990.
[58] Memorandum from Headquarters Department of the Army, 3d Brigade, 1st Infantry Division (Forward), through Commander, 176th Maintenance Battalion, for Commander 325th Maintenance Company, Subject: "VII Corps CARC Painting Policy," December 27, 1990.
[59] Army Materiel Command message, Subject: "Chemical Agent Resistant Coating (CARC) Update," February 6, 1991.

surface-to-air missiles. Therefore, the preferred CARC color for Army aircraft in the desert environment was either the low reflective green paint or the aircraft interior or exterior gray.[60]

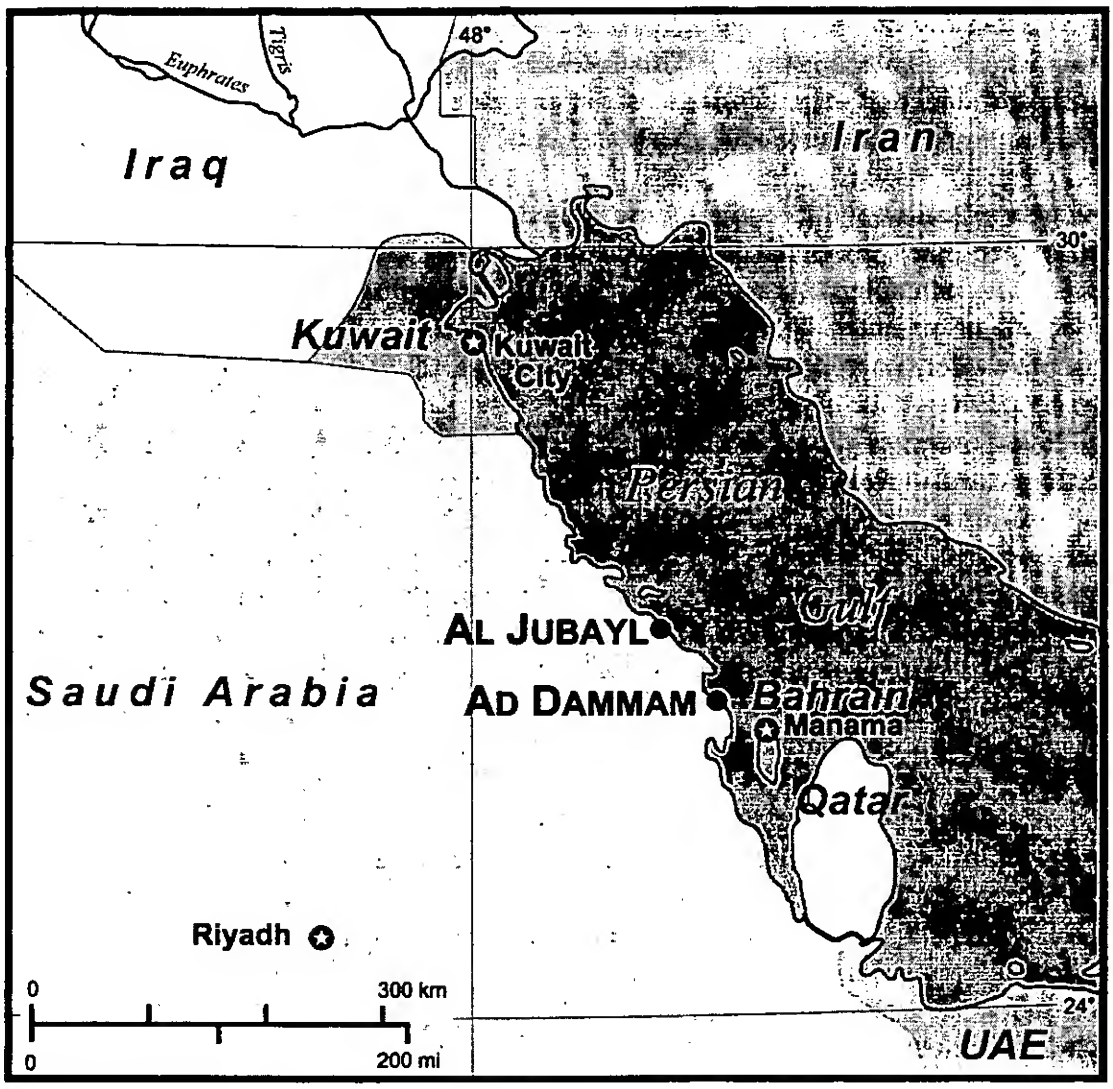

Figure 1. Locations of Ad Dammam and Al Jubayl

C. Major Paint Operations

The vast majority of in-theater painting was conducted at the ports of Ad Dammam and Al Jubayl, Saudi Arabia (see Figure 1). The Army Materiel Command, through the military supply system, supplied the equipment used to support these operations. The equipment included CARC, thinner, solvents, respirators, paint guns, compressors, and hoses. However, because of the urgent need for new and replacement equipment, some of the equipment used during the operations was procured locally from Saudi sources. Plastic hoses, used to carry paint or air, frequently required replacement because they melted and cracked from the high local

[60] Annex J (Service Support) to 3AD Operations Order 90-10, p. J-9.

temperatures. Various solvents were also regularly purchased locally. The locally-procured equipment varied in quality, but served a necessary function in allowing the paint operations to proceed.[61,62] Figure 2 provides a timeline of major events associated with paint operations during the Gulf War. These events will be discussed in greater detail.

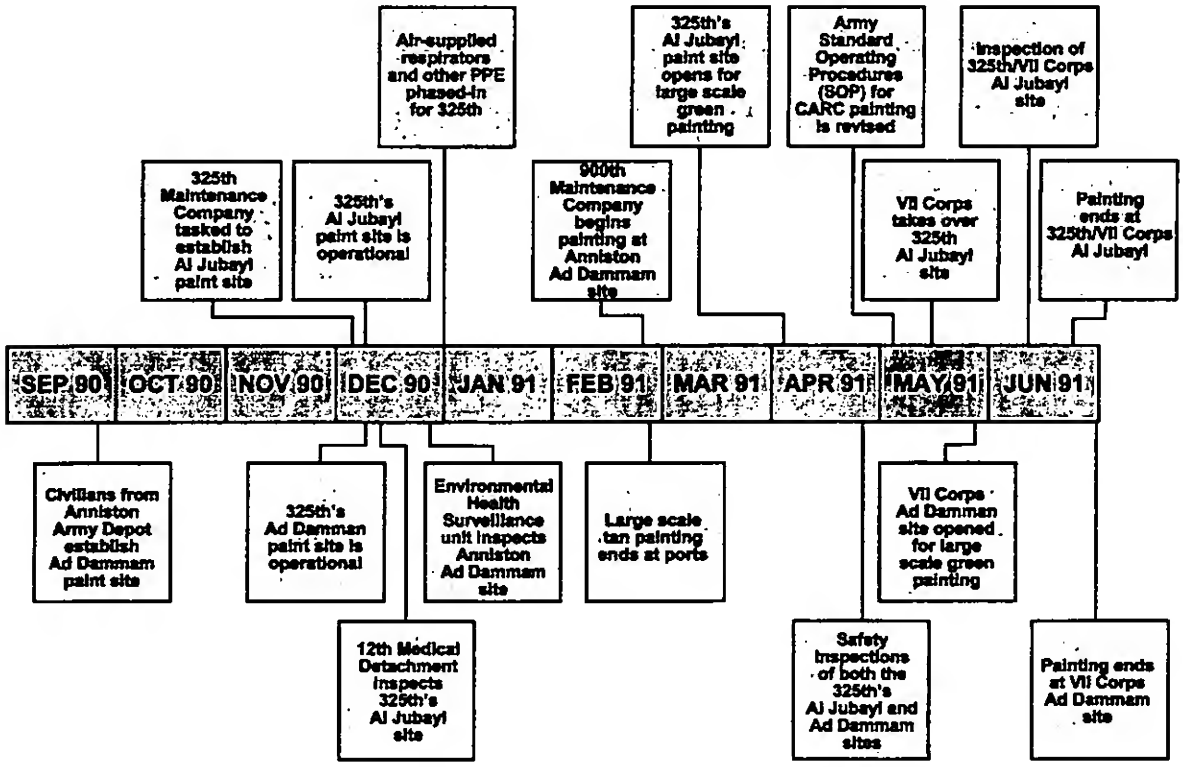

Figure 2. Timeline of major events associated with in-theater painting

1. Department of Army Civilians/900th Maintenance Company at the Port of Ad Dammam

A group of approximately 16 Department of Defense civilians from Anniston Army Depot established the first large-scale, in-theater painting operation in late September 1990 at the port of Ad Dammam. In addition, a small number of civilian contract personnel from various private companies joined them.[63] For purposes of clarity, this operation will be referred to as the Anniston Ad Dammam site.

The Anniston Army Depot personnel set up the paint operation in three large maintenance tents—one for preparatory work and two for painting. They used the preparatory tent for taping and greasing, a process that covers the parts of the vehicle that are not to be painted, such as headlights.[64,65,66] The painters found the evening hours unsuitable for painting due to the high

[61] Lead Sheet #18049, Interview with 593rd Area Support Group senior supply sergeant, July 15, 1998, p. 1.
[62] US Army Environmental Hygiene Agency, Operation Desert Shield / Desert Storm, History of Participation by the US Army Environmental Hygiene Agency, 1992, p. 2-19.
[63] Lead Sheet #18141, Interview with site manager for the Anniston Ad Dammam paint site, July 16, 1998, p. 1.
[64] Lead Sheet #18143, Interview with DoD civilian painter at Anniston Ad Dammam paint site, July 16, 1998, p. 1.

nighttime humidity levels along the Arabian Gulf coast. Atmospheric moisture condensing on the vehicles altered the tint of the paint. Consequently, they painted during the morning and afternoon hours, for up to 16 hours each day.

The painters applied CARC directly on top of the existing CARC surface, without the use of primers and with only minimal surface preparation. Two painters, each equipped with spray guns, painted each vehicle. The larger of the two paint tents accommodated two vehicles at one time, while the smaller paint tent could accommodate only one. Consequently, a total of six painters usually worked at any given time. These two-painter teams usually worked for about one to two hours in their respective paint tents before being replaced by another team.[67]

The experienced CARC painters from Anniston Army Depot brought personal protective equipment with them to the Gulf theater. This equipment included respirators, paint suits, gloves, and boot covers. Several persons from this group report differing types and levels of availability of respiratory protective equipment when painting activities began.[68] By mid-January, the operation had matured significantly, and full-face, air-supplied respirators and other personal protective equipment were available. Based on interviews with several Anniston Ad Dammam paint site civilian painters in 1998, no adverse health effects from the CARC paint operation were reported in our interim report dated February 24, 2000.[69] Subsequently, several civilian painters from Anniston told us of reported respiratory problems that they associate with their CARC painting experiences in the Gulf War.[70] Their comments and concerns were forwarded to the Army's Office of the Surgeon General who has agreed to arrange for further medical follow-up through the occupational medicine clinic at Anniston Army Depot.[71]

In late February of 1991, the 900th Maintenance Company, an Alabama Army National Guard unit, arrived at the Anniston Ad Dammam paint site. The 900th Maintenance Company was a general support maintenance unit primarily tasked to repair tanks. However, the unit had some experience using paint guns, respirators, and personal protective equipment.[72] Following repairs in the maintenance shop, vehicles would go through the paint tents. About ten soldiers from the

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[65] Lead Sheet #18305, Interview with DoD civilian painter at Anniston Ad Dammam paint site, July 27, 1998, p. 1.
[66] Lead Sheet #18301, Interview with DoD civilian painter at Anniston Ad Dammam paint site, July 27, 1998, p. 1.
[67] Lead Sheet #18143, Interview with DoD civilian painter at Anniston Ad Dammam paint site, July 16, 1998, p. 1.
[68] Lead Sheet #18141, Interview with site manager for the Anniston Ad Dammam paint site, July 16, 1998, p. 1; Lead Sheet #18146, Interview with DoD civilian painter at Anniston Ad Dammam paint site, July 16, 1998, p. 1; Lead Sheet #18305, Interview with DoD civilian painter at Anniston Ad Dammam paint site, July 27, 1998, p. 1.
[69] Lead Sheet #18143, Interview with DoD civilian painter at Anniston Ad Dammam paint site, July 16, 1998, p. 1; Lead Sheet #18146, Interview with DoD civilian painter at Anniston Ad Dammam paint site, July 16, 1998, p. 1; Lead Sheet #18305, Interview with DoD civilian painter at Anniston Ad Dammam paint site, July 27, 1998, p. 1; Lead Sheet #18301, Interview with DoD civilian painter at Anniston Ad Dammam paint site, July 27, 1998, p. 1.
[70] Lead Sheet #26418, Interview with DoD civilian painter at Anniston Ad Dammam paint site, March 29, 2000, p. 2, Lead Sheet # 26328, Interview with DoD civilian painter at Anniston Ad Dammam paint site, April 7, 2000, p. 1-2, Lead Sheet #18143, Interview with DoD civilian painter at Anniston Ad Dammam paint site, April 11, 2000, p. 2-3, Lead Sheet #18301, Interview with DoD civilian painter at Anniston Ad Dammam paint site, May 4, 2000, p. 1.
[71] Lead Sheet #27246, Interview with US Army Occupational Medicine Staff Officer, June 28, 2000.
[72] Lead Sheet #17526, Interview with 900th General Supply Maintenance Company painter, January 12, 1999, p.1.

900th Maintenance Company operated the two paint tents used at this site. This group painted approximately 100 vehicles during the tan-painting operation.

A small portion of the group from the Anniston Army Depot remained at the Anniston Ad Dammam site to help train painters and supervise this paint operation. In this configuration, the majority of the painting was done by the soldiers of the 900th,[73] which ensured a smooth transition of the operation to the control of the 900th Maintenance Company. Conversations with several veterans from the 900th have indicated that they believed that their respiratory equipment differed slightly from that used by the civilians. That is, they reported that the civilian painters used better-quality personal protective equipment. There were no identified adverse health reactions experienced among the military paint teams as a result of the painting operation.[74]

Figure 3 shows the command hierarchy for the 325th and 900th Maintenance Companies. These units conducted large-scale CARC spray painting operations in the Kuwait theater of operations.

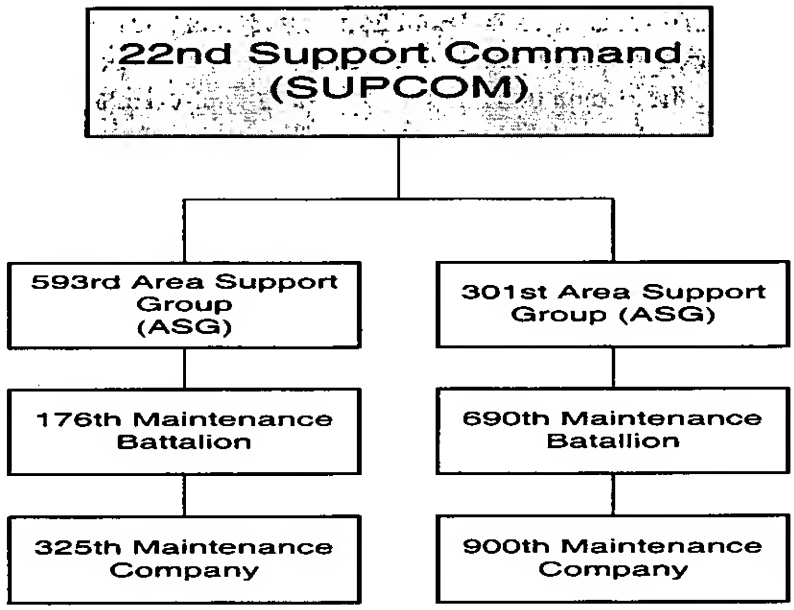

Figure 3. Command relationships of units involved

[73] Lead Sheet #18141, Interview with site manager for the Anniston Ad Dammam paint site, July 16, 1998, p. 1.
[74] Lead Sheet #18259, Interview with 900th General Supply Maintenance Company maintenance warrant officer, July 22, 1998, p. 1; Lead Sheet 18328, Interview with DoD civilian painter at Anniston Ad Dammam paint site, July 28, 1998, p. 1; Lead Sheet #18051, Interview with 900th General Supply Maintenance Company shop officer, July 15, 1998, p. 1.

2. 325th Maintenance Company

a. Tan CARC Painting Operations at the Ports of Ad Dammam and Al Jubayl

The 593rd Area Support Group (ASG) assigned the 325th Maintenance Company, a Florida Army National Guard unit, to establish and operate the theater's two high-volume paint sites, one at Ad Dammam and one at Al Jubayl. (See hierarchy of command chart in Figure 3.) This unit was a direct support maintenance company with no trained painters.[75] It is important to note that the site operated by the 325th at Ad Dammam was a new site, and was not a part of the site established earlier at Ad Dammam by the civilians from Anniston Army Depot. The Ad Dammam paint site operated by the 325th will henceforth be referred to as the 325th Ad Dammam paint site, while the Al Jubayl site will be referred to as the 325th Al Jubayl paint site.

Though the operations were planned prior to the arrival of the bulk of the Army's equipment, the available evidence differs as to the degree to which the operations complied with applicable occupational safety and health precautions. Both the commander of the 593rd ASG and the commander of the 176th Maintenance Battalion stated that the operations commenced with adequate safety measures in place. The commander of the 593rd believed that the operations met OSHA standards (i.e., the occupational safety standards that civilian operations are required to meet). The commander of the 176th explained that an air-purifying respirator was available for each painter. He also reported that safety inspections at the sites had verified that appropriate safety precautions were in place.[76,77]

Although several senior officers indicated that adequate safety measures were implemented, a number of soldiers directly involved with the day-to-day painting operations and various safety officials have contested these claims, stating that proper safety procedures were not in place at the two major paint operations. The officer in charge of the painting operation explained that the greatest problem was a shortage of proper personal protective equipment. From the beginning of the operation, his unit had trouble acquiring parts and equipment. Equipment often took weeks to be delivered to the sites following a request.[78,79,80]

The paint sites established by the 325th at the ports of Ad Dammam and Al Jubayl began operations in December, 1990. The 325th sites consisted of four to six large maintenance tents, with one tent used from time to time for vehicle preparation by vehicle crews. Preparation rarely involved more than spraying off the vehicles with water, occasional light sanding or scraping, and taping and greasing the vehicle windows. The tent flaps were generally left open to allow natural ventilation. Only on occasions when there was a great deal of wind were the tent flaps closed. No engineering ventilation devices, such as fans and blowers, were used in the in-theater

[75] Lead Sheet #15190, Interview with 325th Maintenance Company painter, February 25, 1998, p. 2.
[76] Lead Sheet #15359, Interview with 593rd Area Support Group commanding officer, March 6, 1998, p. 1.
[77] Lead Sheet #15120, Interview with 325th Maintenance Company commanding officer, February 17, 1998, p. 1.
[78] Lead Sheet #15853, Interview with 325th Maintenance Company painter, April 6, 1998, p. 1.
[79] "Logistical Concerns Requiring Assistance." undated.
[80] "Paint Operations at Al Jubayl," equipment tally. undated.

painting operations. As a result, there was typically a noticeable cloud of paint overspray outside the maintenance tents. Figure 4 shows four paint tents at Al Jubayl.[81,82]

Figure 4. Paint tents at Al Jubayl[83]

Daily status reports for CARC painting activities at the Al Jubayl paint site during December 1990 and January 1991[84] recorded the number and type of vehicles and equipment painted per day. The number varied significantly from none to over 200 per day depending on a variety of factors, including the weather, the number of priority vehicles at the site, and the operating status and availability of painting equipment. The status reports also included information on the personnel involved, any problems, concerns or safety issues encountered, dignitary visits, and other comments. Many daily reports do not identify problems or safety concerns, however, the following issues are identified:

[81] Lead Sheet #15853, Interview with 325th Maintenance Company painter, April 6, 1998, p. 1.
[82] Lead Sheet #14254, Interview with 325th Maintenance Company painter, January 26, 1998, p. 1-2.
[83] Photo taken by US Army Support Group safety officer.
[84] 325th Maintenance Company, Daily Report – Al Jabail Port Paint Facility, December 21, 1990 to January 26, 1991, web site www.gulflink.osd.mil/declassimages/army/19960116/011696_117_8_001.html

- Limited quantities of paint thinner and filters for respirators;
- Locally purchased thinner is inadequate for painting at night;
- Compressors breaking down and replacement compressors missing fittings; and
- Hazardous waste disposal.[85]

The majority of the 325th Maintenance Company (roughly 200 people) were directly involved in the painting operations at the two sites. There were approximately 70 soldiers from the unit assigned to each site at any given time, with members of the unit periodically rotating in from assorted duties at the port. There were generally three shifts of paint teams per day at each site. Typical shifts were 7 AM-3 PM, 3 PM-11 PM, and 11 PM-7 AM, although 12-hour shifts were also in place at times. The urgent need to paint as many vehicles as quickly as possible resulted in round-the-clock painting operations despite the concerns noted earlier with nighttime painting. The soldiers at the 325th Ad Dammam paint site slept in buildings about a mile away from the paint site. At the 325th Al Jubayl paint site, however, the soldiers slept in tents that were approximately 50-200 yards away from the paint tents. In fact, the paint tents, showers, mess storage, latrines, and sleeping quarters were all collocated in a topographical depression about a city block in length and width, outside of the port of Al Jubayl. As a result, some of the personnel assigned to the site indicated an overspray haze often shrouded the entire 325th Al Jubayl paint site compound.[86]

In general, the most important health and safety issue associated with a CARC painting operation is the proper use of personal protective equipment. The primary complaint of many of the soldiers from the 325th was that the appropriate personal protective equipment was not available to them during the painting operations. Numerous reports of unsafe practices have been received from veterans, including the use of face shields taped to standard military helmets, torn paper coveralls, standard issue chemical protective masks, improper mask filter cartridges, and paper surgical masks. Members of the 325th had no formal training and little practical experience as painters, and received no training in the use of air-supplied respirators.[87]

Due to soldier complaints, improved personal protective equipment was gradually phased-in at the 325th Ad Dammam and Al Jubayl paint sites. For example, within several weeks of the beginning of the paint operations, air-supplied respirators, proper gloves and coveralls, and air hoses arrived. Explosion-resistant lighting was also added at a later date. The air-supplied respirators significantly improved the respiratory protection of the painters. Figure 5 shows a

[85] 325th Maintenance Company, Daily Report – Al Jabail Port Paint Facility, December 21, 1990 to January 26, 1991, web site www.gulflink.osd.mil/declassimages/army/19960116/011696_117_8_001.html

[86] Lead Sheet #14346, Interview with 325th Maintenance Company mechanic, February 4, 1998, p. 1; Lead Sheet #15190, Interview with 325th Maintenance Company painter, February 25, 1998, p. 2; Lead Sheet #14228, Interview with 325th Maintenance Company painter, January 21, 1998, p. 1-2; Lead Sheet #14978, Interview with 325th Maintenance Company painter, February 10, 1998, p. 1.

[87] Lead Sheet #15853, Interview with 325th Maintenance Company painter, April 6, 1998, p. 1; Lead Sheet #14254, Interview with 325th Maintenance Company painter, January 26, 1998, p.1; Lead Sheet #14346, Interview with 325th Maintenance Company mechanic, February 4, 19998, p. 1; Lead Sheet #14228, Interview with 325th Maintenance Company painter, January 21, 1998, p. 1-2; Lead Sheet #14978, Interview with 325th Maintenance Company painter, February 10, 1998, p. 1.

soldier from the 325th wearing air-supplied respiratory protection while spraying tan CARC onto a tank. However, soldiers mixing CARC or helping to carry hoses were reportedly not always given respirators.[88] The compressors in use at the site reportedly broke down frequently and were inadequate. By March, the paint team received a high-pressure compressor, that was capable of supporting more than one respirator through a manifold system.[89] In addition, due to a shortage of air hoses, the air compressors (which carry the air from a source to the painter's respirator) were placed in close proximity to the paint tents. As a result, air contaminated with some amount of overspray could have been pumped into the respirators. Painters from different shifts reportedly shared these respirators, yet rarely cleaned or serviced them.[90]

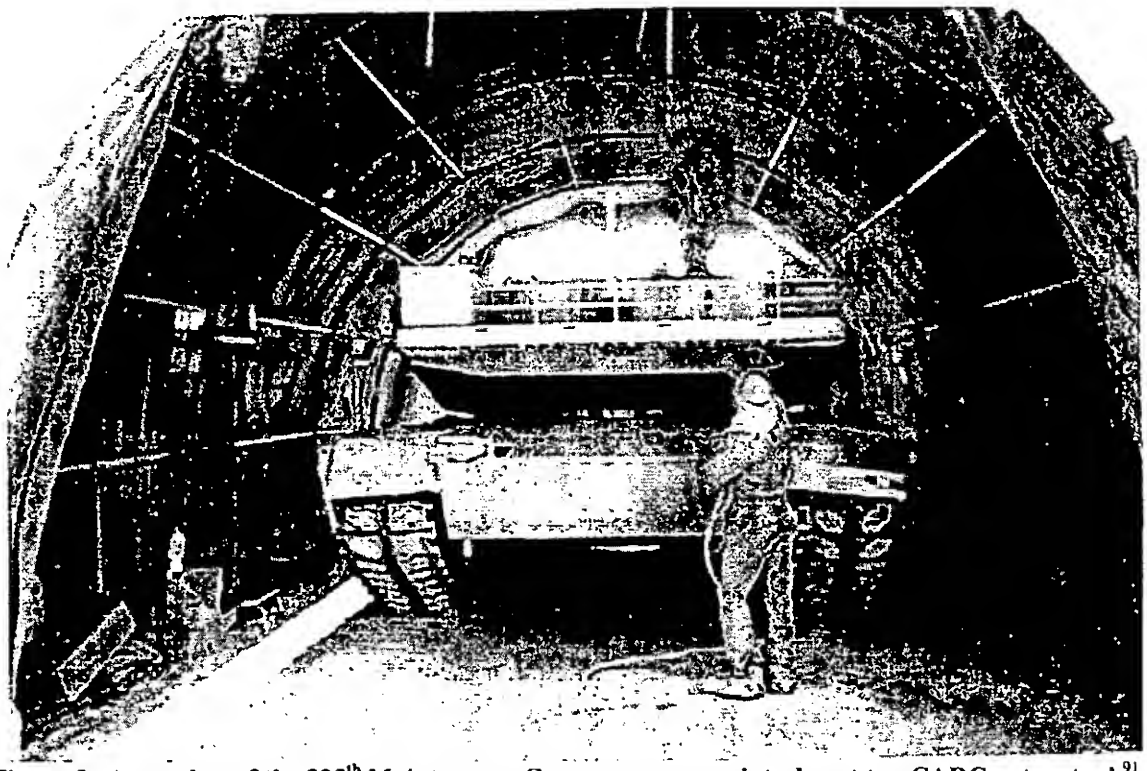

Figure 5. A member of the 325th Maintenance Company spray paints desert tan CARC onto a tank[91]

Training and education is another important aspect of health and safety. Soldiers contacted for this investigation have complained that requests for training were generally ignored by their

[88] Lead Sheet #15853, Interview with 325th Maintenance Company painter, April 6, 1998, p. 1; Lead Sheet #14978, Interview with 325th Maintenance Company painter, February 10, 1998, p. 1.
[89] Lead Sheet #24332, Interview with air compressor manufacturer representative, July 14, 1999, p. 1.
[90] Lead Sheet #15853, Interview with 325th Maintenance Company painter, April 6, 1998, p. 1; Lead Sheet #14346, Interview with 325th Maintenance Company mechanic, February 4, 1998, p. 1; Lead Sheet #14978, Interview with 325th Maintenance Company painter, February 10, 1998, p. 1.; Lead Sheet #21577, Notes from watching video of paint site inspections taken by 22nd Support Command safety officer, February 5, 1999, p. 1.
[91] Photo taken by 325th Maintenance Company commanding officer.

leaders, and material safety data sheets, as well as military training tools such as video tapes[92] and guidance (which are supposed to be readily accessible), were rarely available.[93]

A number of soldiers from the 325th experienced symptoms in-theater that they attributed to exposure to CARC. Eight members of the 325th were interviewed about the symptoms that they or others experienced while working with CARC. Several members of the 325th developed respiratory symptoms, including cough and chest tightness, promptly after starting to work with CARC. In addition, several members developed other symptoms, including headaches, nausea, vomiting, and dizziness, that are consistent with exposure to solvents.[94] There were no reports of instances of serious health problems such as hypersensitivity pneumonitis[95] which can be associated with severe exposure to the HDI in CARC. However, some soldiers were sent back to the unit's headquarters at Ad Dammam to be temporarily removed from the paint detail.[96]

b. Green CARC Painting Operations for Redeployment

Shortly after the cessation of hostilities in the Kuwait Theater of Operations, there was an immediate need to plan and execute the large-scale redeployment of over half a million US troops to their Stateside or European bases and installations For VII Corps, this involved returning a large number of vehicles to Europe. Many of these vehicles had been painted desert tan and needed to be returned to their original woodland camouflage pattern suitable for central Europe. By mid-March the commander of VII Corps had issued guidance that the Corps was to attempt to repaint all tracked and wheeled vehicles and helicopters with the three-color CARC woodland camouflage pattern prior to returning to Europe. The VII Corps Command suggested that this be accomplished at the ports of Al Jubayl and Ad Dammam.[97] Due to the experiences from the pre-war painting operations, military planners anticipated that the redeployment operations would be safer and would adhere more closely to established military guidelines. A safety sheet and concept of operations document, for example, directed the strict safety measures and processes that were to be followed at the Al Jubayl site.[98,99]

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[92] Tape TVT 3-40, "(CARC) Chemical Agent Resistant Coating," and Tape TVT 3-29, "CARC/CPP (Chemical Agent Resistant Coating/Camouflage Pattern Painting," were in existence during Desert Shield/Storm.

[93] Lead Sheet #14346, Interview with 325th Maintenance Company mechanic, February 4, 1998, p. 1; Lead Sheet #14978, Interview with 325th Maintenance Company painter, February 10, 1998, p. 1; Lead Sheet #15190, Interview with 325th Maintenance Company painter, February 25, 1998, p. 1.

[94] Lead Sheet #14346, Interview with 325th Maintenance Company mechanic, February 4, 1998, p. 1; Lead Sheet #19487, Interview with 325th Maintenance Company painter, October 16, 1998, p. 1; Lead Sheet #14228, Interview with 325th Maintenance Company painter, January 21, 1998, p. 2; Lead Sheet #14978, Interview with 325th Maintenance Company painter, February 10, 1998, p. 2; Lead Sheet #15190, Interview with 325th Maintenance Company painter, February 25, 1998, p. 2; Lead Sheet #14254, Interview with 325th Maintenance Company painter, January 26, 1998, p. 2; Lead Sheet #15853, Interview with 325th Maintenance Company painter, April 6, 1998, p. 1; Lead Sheet #21081, Interview with 325th Maintenance Company painter, January 13, 1999, p. 2.

[95] Hypersensitivity pneumonitis is a condition in which lung tissue is highly sensitive and easily inflamed by certain stressors. This is a type of chronic pneumonia caused by a chemical such as HDI or certain microorganisms.

[96] Lead Sheet. #15853, Interview with 325th Maintenance Company painter, April 6, 1998, p. 1; Lead Sheet #15190, Interview with 325th Maintenance Company painter, February 25, 1998, p. 2.

[97] VII Corps message, Subject: "Commander's SITREP #55," March 12, 1991.

[98] VII Corps safety officer, "Jubail Paint Site Safety Information."

[99] VII Corps safety officer, "Jubail Paint Site Concept of Operations."

The requirement to paint vehicles with the three-color woodland pattern, rather than the previous, uniform olive drab, was reemphasized on March 23rd by the 22nd Support Command (SUPCOM).[100] However, by April 13th, this requirement had been altered. Instead of the three-color woodland pattern, the SUPCOM planned for one coat of olive drab paint.[101] This guidance ultimately proved to be the final decision, as those vehicles that were painted prior to redeployment only received one coat of olive drab. This coating was put directly on top of the existing (tan) CARC layer, which was often the same coating hastily applied just a few months earlier. Many of the tan coatings were in poor shape, with paint visibly flaking off due to the lack of surface preparation prior to paint application.[102] Nevertheless, surfaces were generally only washed with water before the redeployment olive drab coating was applied. Army Materiel Command (AMC) reported on the morning of April 24th that this redeployment painting would begin the following day.[103]

Redeployment painting operations were reestablished in Ad Dammam and Al Jubayl. The redeployment painting operations saw improved working conditions. Improved training and guidance along with appropriate personal protective equipment and other task-related equipment were in place before the initiation of painting. For example, from the outset, full-face air-supplied respirators were available. Unfortunately, there is some evidence that respirator and compressor filter maintenance, at least, were still not up to approved safety standards. Further, not all of the air compressors in use were designed to provide breathing quality air, called Grade D. Instead, some of the air compressors were standard shop compressors designed for routine maintenance tasks.[104,105] Likewise, not all personal protective equipment was suited to the task; examination of paint hoods by a 22d SUPCOM civilian safety professional officer revealed that paint was getting into some of the hoods.[106,107,108]

In addition to the general improvement in personal protective equipment, a significant improvement in safety was made with the relocation of the 325th Al Jubayl paint site to higher ground, roughly one mile away from the sleeping, eating, and administrative areas of the operation. This site was set-up in a line along a road that was roughly 75 feet wide and 1000 feet long. Figure 6 shows the arrangement of paint tents at the 325th redeployment paint site at Al Jubayl. Figure 7 shows the location of the 325th Al Jubayl paint site and layout of its major features. In mid-May, after about a month of operating the redeployment sites, the 325th Maintenance Company turned over site operations to personnel from VII Corps.[109]

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[100] VII Corps Redeployment LNO Coordinator Notes #6, SUPCOM Evening Brief, 23 MAR 91, March 25, 1991.
[101] VII Corps Redeployment LNO Coordinator Notes #24, SUPCOM Evening Stand-up, 12 Apr 91, April 13, 1991.
[102] Lead Sheet #21577, Notes from watching video of paint site inspections taken by 22nd Support Command safety officer, February 5, 1999, p. 1.
[103] VII Corps LNO to 22D SUPCOM Notes #35, SUPCOM Morning Stand-up 23 APR 91, April 24, 1991.
[104] Journal of a 22nd Support Command safety officer, p. 11.
[105] Journal of a 22nd Support Command safety officer, p. 13.
[106] Lead Sheet #21577, Notes from watching video of paint site inspections taken by 22nd Support Command safety officer, February 5, 1999, p. 1.
[107] Journal of a 22nd Support Command safety officer, p. 8.
[108] Journal of a 22nd Support Command safety officer, p. 13-14.
[109] Lead Sheet #15853, Interview with 325th Maintenance Company painter, April 6, 1998, p. 1-2; Lead Sheet #15190, Interview with 325th Maintenance Company painter, February 25, 1998, p. 1.

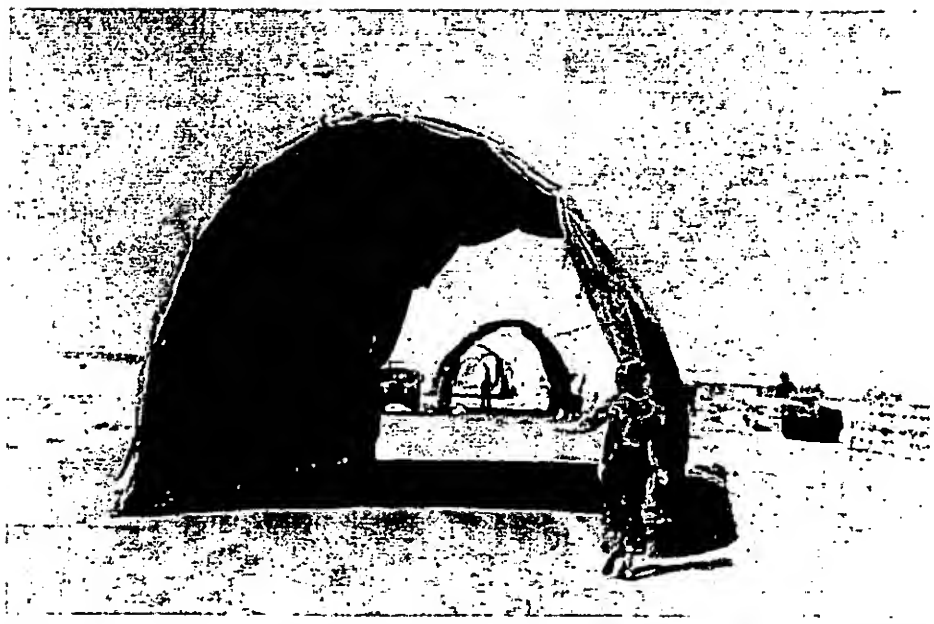

Figure 6. The redeployment paint site at Al Jubayl was set-up along an unused road[110]

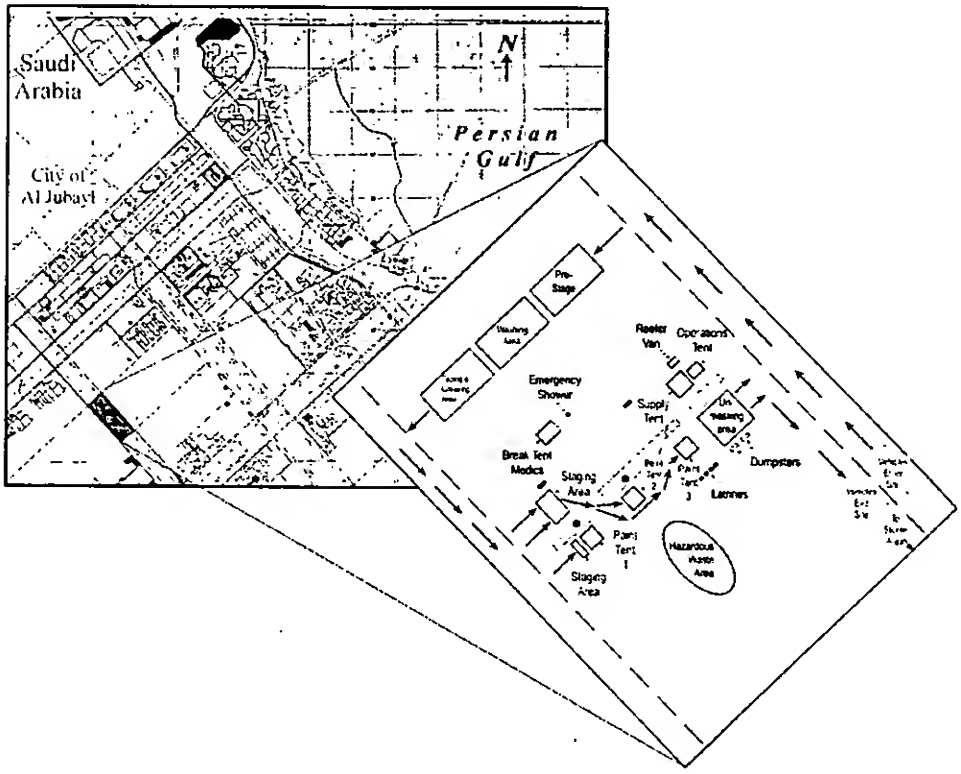

Figure 7. Location and major features of the VII Corps redeployment paint site at Al Jubayl[111]

[110] Photo taken by US Army Support Group safety officer.

[111] Lead Sheet #19604, Map provided by US Army Support Group safety officer, February 10, 1999.

Rather than immediately taking over the paint operations, VII Corps suspended operations until the arrival of additional safety equipment.[112,113] By May 10, 1991, VII Corps had commenced full-scale painting. By this time, almost 20,000 gallons of paint, 4,000 gallons of paint thinner, explosion-resistant lighting, and air compressors were on hand. The air-supplied respirators, air hoses, paint guns, and lighting were all new. In addition, carbon monoxide alarms, air pressure gauges, and respirator pre-filters were all available. This equipment was set-up in advance of the initiation of the paint operation by safety professionals.[114] Figure 8 shows a painter at the Al Jubayl redeployment paint site wearing a paint suit and air-supplied respirator with a cooling vortex—a vast improvement over some of the previous practices and procedures.

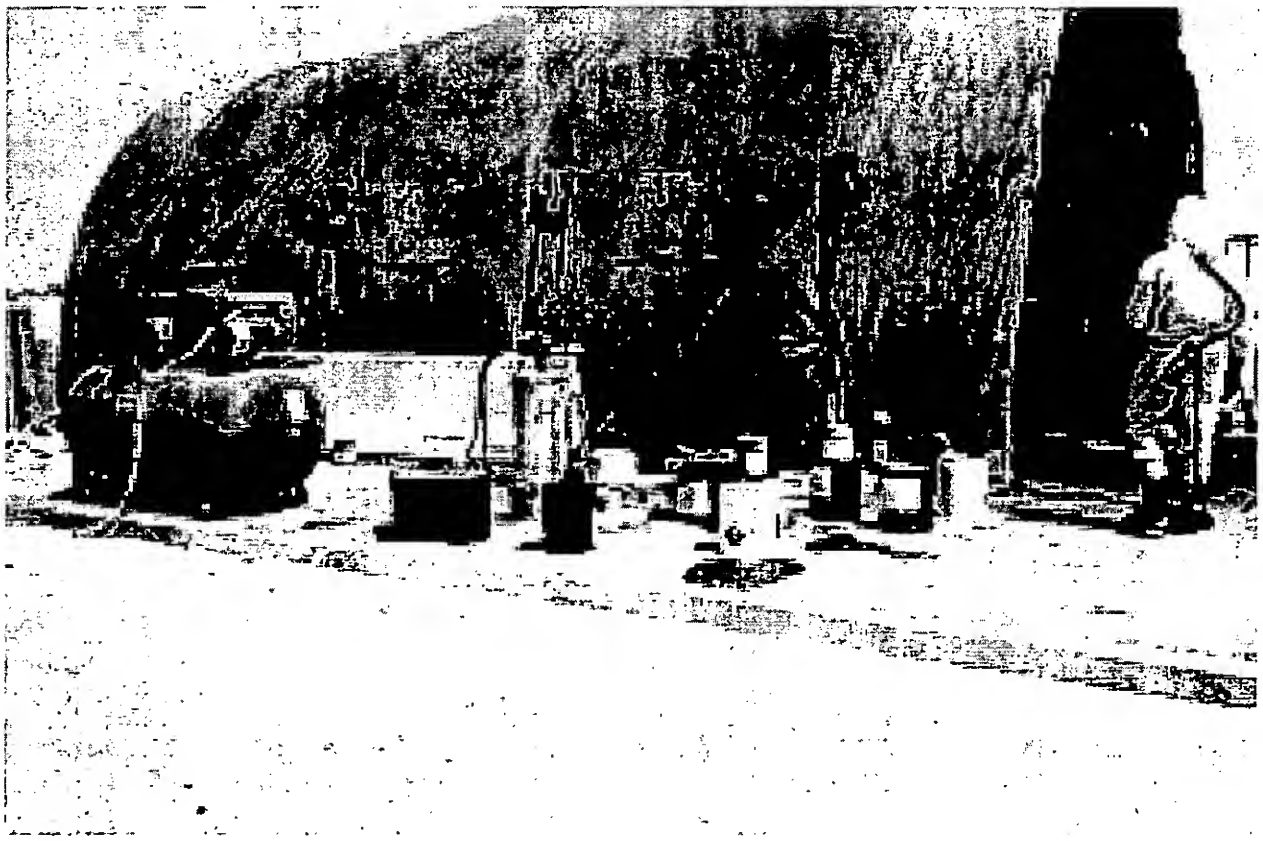

Figure 8. Painter wearing an air-supplied respirator[115]

In addition to the paint site at Al Jubayl, units from VII Corps were tasked to operate a redeployment paint site at the port of Ad Dammam. This operation was established by safety professionals before the initiation of the painting operation. New air compressors, hoses, air-supplied respirators, filters, carbon monoxide alarms, explosive resistant lighting and electrical

[112] Army Materiel Command/US Army Support Group (Provisional), Operation Desert Storm Saudi Arabia, safety officer, 15 January 1991 – 21 July 1991, briefing slides.
[113] Lead Sheet #19604, Interview with US Army Support Group safety officer, October 22, 1998, p. 3.
[114] Lead Sheet #21577, Notes from watching video of paint site inspections taken by 22nd Support Command safety officer, February 5, 1999, p. 1-2.
[115] Photo taken by US Army Support Group safety officer.

outlets, and various personal protective equipment were available at Ad Dammam.[116] Figure 9 shows the set-up of air compressors and filters used at the redeployment paint operation at Ad Dammam. This operation was located in the same general area of the port as the previous paint site at Ad Dammam operated by the 325th. Figure 10 shows the location of the paint site and the layout of its major features.

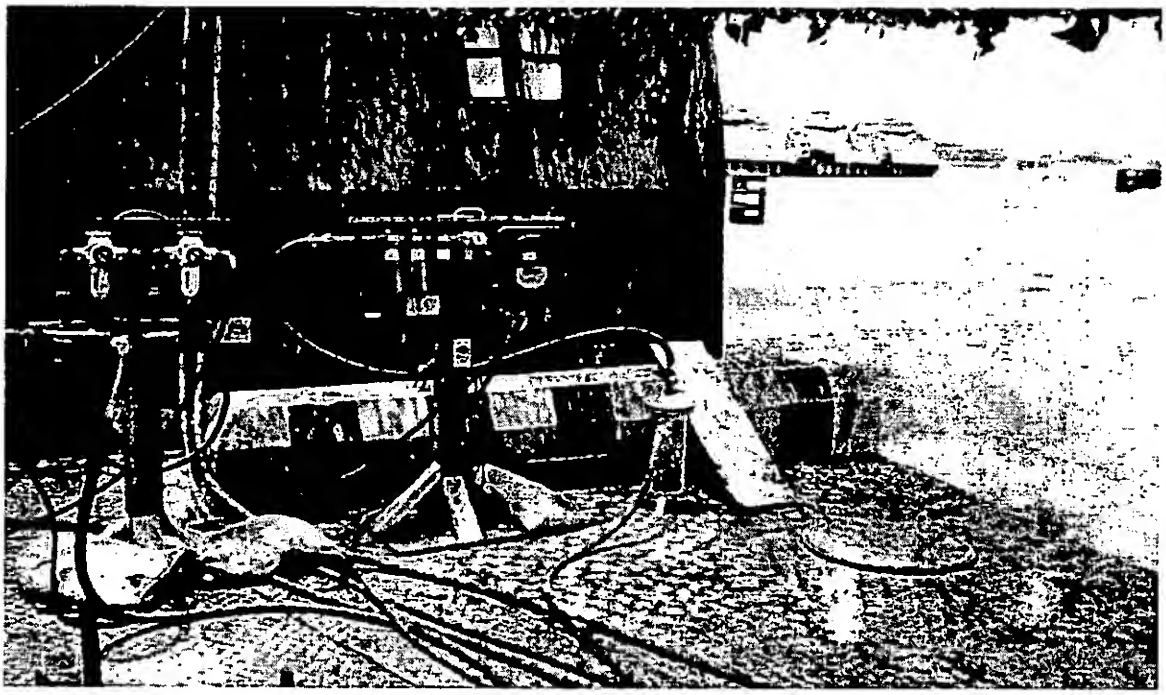

Figure 9. Alarm panel for a high-pressure breathing air system at Ad Dammam[117]

Another in-theater redeployment paint operation was established at Camp Doha in Kuwait. This small-scale operation was established to apply tan paint to a number of olive drab-colored vehicles designated for continuing in-theater operations. The 11th Armored Cavalry Regiment (ACR), which arrived in-theater after the war's end, took receipt of these vehicles from King Khalid Military City (KKMC) in Saudi Arabia. In late June, 1991, an advance party of Department of the Army civilians from the US Army Support Group set up the site, including safety inspections and electrical wiring.[118] The civilians stayed at the site for the first few days of the operation to train non-specialist members of the 11th ACR in painting and safety procedures. Given the attention to safety during the setup at Camp Doha, and the application of lessons learned during earlier in-theater CARC painting operations, this particular operation was considered by an in-theater safety officer to be safe. The operation ceased on July 11th, 1991, following a motor pool fire that resulted in the destruction of many of the 11th ACR's vehicles, munitions, and equipment.[119]

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[116] Lead Sheet #20618, Interview with 22nd Support Command safety officer, February 16, 1999, p. 2.
[117] Photo taken by US Army Support Group safety officer.
[118] Memorandum from USASG-F to Commander, 22nd Support Command (TAA), Subject: "Kuwait Passes for Official Duty," June 21, 1991.
[119] Lead Sheet #19604, Interview with US Army Support Group safety officer, October 22, 1998, p. 2.

A combined total of 3216 tracked and 5248 wheeled vehicles were painted olive drab during the redeployment at all sites.[120]

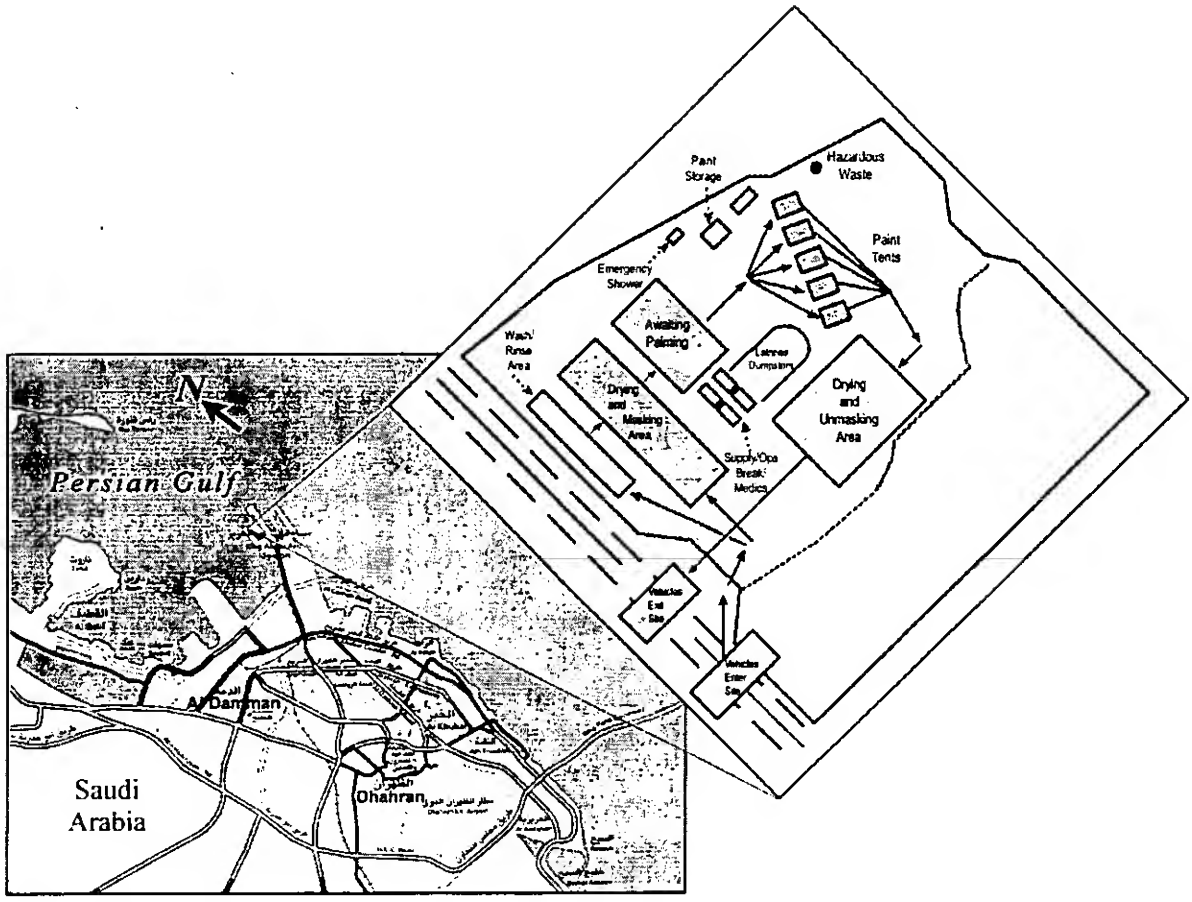

Figure 10. Location and major features of the VII Corps Ad Dammam redeployment site[121]

3. Other Sites

In addition to the painting done by the large-scale spray paint operations at Ad Dammam and Al Jubayl, a number of short-term, small-scale paint operations existed in theater. This follows the policy decision which allowed non-combat, lower-priority vehicles to move out of the port area without being painted tan. The 3rd Armored Cavalry Regiment (ACR) operated one such paint operation. In December of 1990, while in the vicinity of Camp Cactus (an assembly area several hundred miles west of Ad Dammam), members of the 3rd ACR were tasked to CARC paint vehicles. The unit tasked approximately three to six soldiers to spray-paint vehicles, and provided them with paper surgical masks for protection. However, the operation lasted only about three days, and the two painters from this group who were contacted reported that they had not experienced any adverse health effects attributable to CARC exposures, and were unaware of

[120] "E-10 CARC Painting Operations." Undated.
[121] Lead Sheet #19604, Map provided by US Army Support Group safety officer, February 10, 1999.

any such symptoms experienced by other paint detail members.[122] Other short duration, low-volume spray-painting operations, like the one undertaken at Camp Cactus, were not uncommon in the theater.

A number of other soldiers were also involved in short-term, spot/touch-up painting operations throughout the Kuwait Theater of Operations. Soldiers from the 24th Infantry Division and the 89th Military Police Brigade, for example, are known to have conducted spot/touch-up painting.[123] Adverse health effects from these types of operations would not be expected, and have not been reported. This is due to the use of brushes and rollers, rather than spray guns, which limits aerosolization of the paint. In addition, the short-term nature and less-intense workload of these smaller operations probably limited the extent of potential exposures.

D. Health and Safety Inspections of the CARC Painting Operations

Due to the safety hazards associated with CARC painting, it became necessary to conduct paint site inspections. The need for industrial hygiene and occupational medicine support for heavy maintenance and CARC painting was identified in October 1990, well before the bulk of US forces were deployed.[124]

In late 1990, an environmental health surveillance group from the 105th Medical Detachment conducted an inspection at the Anniston Ad Dammam paint site. This medical surveillance group looked at the operation's processes from an environmental and industrial hygiene standpoint. When the group arrived, they observed that the painters were using air-purifying respirators and were working 12-hour shifts. They also noted that there was one painter in each tent, with another painter doing touch-up work outside each tent. To improve safety procedures, the inspection team procured air-supplied respirators that arrived within a week. Each painter was eventually issued an individual air-supplied respirator. Despite these deficiencies, the surveillance unit observed no health problems and was not informed of any that had occurred prior to their arrival. The inspection team was very impressed by the maintenance team commander's quick response to safety improvement suggestions. Given the urgency of the mission, the commander of the surveillance team felt that the protection measures being taken by the maintenance unit were sufficient.[125]

The 325th Maintenance Company's Ad Dammam and Al Jubayl paint sites were inspected on several occasions. Individual members of the 325th Maintenance Company experienced overexposures to CARC painting during the week of December 10, 1990. Symptoms exhibited indicated short-term exposure to solvents as well as to isocyanates. As a result, an industrial hygiene and safety evaluation was conducted from December 17-19 at the Al Jubayl painting

[122] Lead Sheet #14234, Interview with 3rd Armored Calvary Regiment painter, January 22, 1998, p. 1; Lead Sheet #14237, Interview with 3rd Armored Calvary Regiment painter, January 22, 1998, p. 1-2.
[123] Lead Sheet #15548, Interview with 24th Infantry Division painter, March 24, 1998, p. 1; Lead Sheet #15881, Interview with 89th Military Police Brigade painter, April 7, 1998, p. 1.
[124] ARCENT message, Subject: "Occupational Medicine/Industrial Hygiene Support to DESCOM," October 29, 1990, p. 1.
[125] Lead Sheet #14270, Interview with 105th Medical Detachment environmental science officer, January 28, 1998, p. 1.

operation. During the evaluation, discussions were held with the commander of the 176th Maintenance Battalion and with the commander and members of the 325th Maintenance Company. According to the report, "The cause of the overexposure resulted from inadequate engineering controls and inadequate use of appropriate respiratory protection and personal protective clothing."[126]

In a December 15, 1990, memorandum, an Army Central Command (ARCENT) safety director reported on the situation at the 325th Ad Dammam paint site. The memorandum describes soldiers experiencing adverse health reactions to the painting duty, including rashes, vomiting, nausea, and dizziness. The memorandum goes on to explain that one of the officers from the 176th Maintenance Battalion, the unit under which the 325th falls, was "very concerned for the welfare of his soldiers but was also interested in doing the job." Despite well-established Army safety protocols, the 325th Maintenance Company was told to use standard-issue M-17 NBC masks for respiratory protection. These masks are filter respirators designed for protection against chemical warfare agents and do not have the proper filters to protect against the aerosolized isocyanates found in CARC.[127] Using them for industrial hygiene applications, especially painting, would rapidly degrade their ability to provide protection against chemical or biological warfare (CBW) agents, as the filters would quickly become saturated by paint and would require frequent replacement.

On December 16, 1990, four inspectors from the 12th Medical Detachment arrived at the 325th Al Jubayl paint site to observe practices and procedures being followed by the 325th Maintenance Company's painters. The inspection group consisted of an industrial hygienist, an occupational medicine physician, and two enlisted personnel. Upon arrival, the group noted that the painters were wearing chemical protection masks, assorted air-purifying respirators, and standard battle dress utility (BDU) uniforms with no protective overgarments. To correct this situation, the inspection team's industrial hygienist bought enough certified low-pressure air-supplied respirators from a local store to equip the painters. The team also ordered several more respirators so that personnel participating in all aspects of the paint operation could have air-supplied respirators. Though no one present was qualified to fit-test soldiers for the air-supplied respirators, the inspection team's industrial hygienist believed that the painters were still adequately protected. In addition, the team gave suggestions as to where the air compressors for the respirators should be placed for optimal performance and protection.[128, 129]

While at the site, the occupational medicine physician evaluated 19 soldiers of the 325th Maintenance Company. The team physician found that five soldiers had symptoms possibly related to inhalation of solvent fumes, and fourteen soldiers had possible symptoms from contact

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[126] Memorandum from 12th Medical Detachment for Commander, 176th Maintenance Battalion, Subject: "Industrial Hygiene and Safety Evaluation of 'CARC' Painting Operations," December 20, 1990, p. 2.

[127] Memorandum for Record from Safety Director, Subject: "Hazard report, CARC painting operation," December 15, 1990.

[128] Lead Sheet #14379, Interview with 12th Medical Detachment industrial hygienist, February 9, 1998, p. 1; Lead Sheet #14369, Interview with CARC paint site inspector, February 6, 1998, p. 1.

[129] Memorandum for Record from SUPCOM, Surgeon/CDR, SUPCOM Med Grp (Prov), Subject: "CARC Painting," p. 1, web site www.gulflink.osd.mil/declassdocs/army/19961108/110596_aug96_decls1_0002.html (as of January, 21, 2000)

with HDI in the paint. This physician recalls seeing nausea, dizziness, and conjunctival irritation (irritation to the mucous membrane of the eyes) in the painters.[130] Each soldier who was evaluated was personally briefed on appropriate safety measures, told to avoid further contact with the HDI-based CARC, and told that they could continue painting if they were totally protected from contact with the paint. No long-term after-effects were expected for the 19 personnel. Unit leaders were also briefed on proper safety procedures. The inspection team left the site on December 19, 1990.[131,132]

Instructions were provided on the proper use of the respirator and the wearing of other protective equipment during the evaluation. In addition, other control measures were implemented to reduce exposures, including the establishment of a restricted area where certain levels of protective clothing were required depending on the job performed, 8-hour work shifts, a job rotation system, and the establishment of a break area away from the paint site.[133]

The actions taken by the 176th Maintenance Battalion were viewed as a practical and effective short-term fix for a low production painting operation (up to 50 vehicles per day). The evaluation report indicated that if a higher production rate was required (100 to 200 vehicles per day), health problems would resurface and additional controls would need to be implemented.

Health and safety recommendations for a higher production rate included:

- All personnel working in and around the CARC painting and mixing areas would require a full-face air-line respirator, approved personal protective clothing and equipment, and hand and foot protection (e.g. gloves and boot covers).
- Although air-line systems should be capable of providing breathing quality air, the location of the air intakes for the compressors must be in a protected area or an area as remote as possible from the source of contamination. Filtration systems must also be maintained according to the manufacturers' specifications.
- Additional mechanical agitators and/or mixers would need to be acquired to reduce exposures due to the manual stirring and mixing of CARC paint.
- A steady flow of respiratory protective equipment and personal protective equipment would need to be delivered to the paint site. It might become necessary to locally purchase needed items if normal supply channels prove unable to provide the needed equipment on time.
- Fire extinguishers designed to extinguish flammable liquid fires would need to be placed in the vicinity of each painting or mixing operation. The solvent carriers for CARC paint are flammable.

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[130] Lead Sheet #14390, Interview with 12th Medical Detachment occupational medicine physician, July 8, 1999, p 2.

[131] Memorandum for Record from SUPCOM, Surgeon/CDR, SUPCOM Med Grp (Prov), Subject: "CARC Painting," p. 1, web site www.gulflink.osd.mil/declassdocs/army/19961108/110596_aug96_decls1_0002.html (as of January, 21, 2000)

[132] Memorandum from 12th Medical Detachment, for Commander, 176th Maintenance Battalion, Subject: "Industrial Hygiene and Safety Evaluation of 'CARC' Painting Operation," 20 December 1990, p. 1.

[133] Memorandum from 12th Medical Detachment for Commander, 176th Maintenance Battalion, Subject: "Industrial Hygiene and Safety Evaluation of 'CARC' Painting Operations," December 20, 1990, p. 2.

- The concept of a restricted area and an emphasis on the importance of good personnel hygiene among unit members after they have finished painting operations needs to be enforced.
- A point-of-contact with the 12th Medical Detachment needs to be identified.[134]

In early April 1991, a safety official indicated that the tan CARC painting operations that had taken place through February did not meet safety standards and strongly recommended against the redeployment operations if they were going to be conducted in the same manner.[135] He also expressed doubts that a quality paint job could be conducted under the existing conditions and with the available resources.[136] Specific deficiencies requiring correction prior to the redeployment painting operations included:

- Maintain a safe distance of at least 50 feet between flammable liquids (e.g., paints and solvents) from potential sources of ignition;
- Ensure that all electrical equipment, including light fixtures, cord sets, switches, and other components in paint areas, as well as adjacent areas, are explosive proof;
- Ground and bond all equipment to prevent build up static electricity;
- Provide and maintain proper respiratory protection, including: use of approved pressure-demand or continuous flow type C, full-face piece, hood or helmet supplied air respirator; provision of filters, carbon monoxide alarms, and air coolers to air compressors; testing of breathing air; fit testing of respirators of selected personnel; medical screening and monitoring of personnel, including pulmonary function tests; and implementation of a maintenance program to clean, sanitize, repair, and adjust respirators;
- Ensure that spray operations are conducted in tents of noncombustible cloth or cloth that has been treated; and that the tents are cleaned of flammable overspray on a regular schedule;
- Provide all personnel involved in paint operations with respiratory training and hazard communication training;
- Provide stand-by emergency medical service and medical monitoring, as well as emergency decon facilities;
- Provide sufficient room to prevent downwind exposures to personnel.[137]

In late April/early May, 1991, shortly after the initiation of redeployment painting operations at the Ad Dammam port, a safety inspection and tour of the paint facility was conducted. Though the facility was a 22nd Support Command operation, the inspection team brought two VII Corps general officers through the 325th Ad Dammam paint site. The team was led by a VII Corps safety manager, and included a command surgeon and a second safety manager. This inspection revealed safety problems that were significant enough to warrant halting the paint operations. In

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[134] Memorandum from 12th Medical Detachment for Commander, 176th Maintenance Battalion, Subject: "Industrial Hygiene and Safety Evaluation of 'CARC' Painting Operations," December 20, 1990, p. 2-3.
[135] Memorandum Record from Department of the Army, Army Materiel Command, United States Army Support Group, Subject: "Paint Operations in SWA," April 5, 1991, p. 1.
[136] Memorandum Record from Department of the Army, Army Materiel Command, United States Army Support Group, Subject: "Paint Operations in SWA," April 5, 1991, p. 3.
[137] Memorandum Record from Department of the Army, Army Materiel Command, United States Army Support Group, Subject: "Paint Operations in SWA," April 5, 1991, p. 1-2.

particular, the safety manager found that the air compressors in use were not designed to supply quality air fit for breathing. Based on that assessment, the proper air compressors were ordered and flown to the site. Operations resumed several days later when the safety issues had been resolved.[138]

On the 25th and 26th of April, 1991, another inspection team visited the 325th Maintenance Company's Al Jubayl and Ad Dammam paint sites. This team consisted of a civilian safety specialist and the industrial hygienist and one enlisted soldier from the 12th Medical Detachment's December 16th inspection team. After conducting an inspection, the team noted a number of problems at each site. Some of the problems found at the 325th Al Jubayl site were:[139]

- Electrical lighting equipment used within the vapor hazard area was not explosion proof;
- Air compressors providing the breathing supply were not oilless, and carbon monoxide alarms were not present. Due to the load on the compressors, the generation of carbon monoxide (CO) and/or filter overload was determined to be imminent;[140]
- Filters used to remove foreign material from the breathing air did not appear to have been regularly serviced;
- Flammable debris, such as paint- and solvent-soaked rags, and open paint and solvent containers littered the area in and around the paint mixing and spraying tents;
- Personal protective equipment hoods for painters were insufficiently stocked; and
- Paint was reaching the inside of the hoods.

The inspection of the 325th Ad Dammam paint site disclosed many of the same safety deficiencies as were found at the 325th Al Jubayl site. Based upon an examination of the equipment and procedures being followed, the inspection team recommended that paint operations be suspended at the 325th Al Jubayl site and slowed at 325th Ad Dammam site. Additionally, the team suggested that the second paint site at Ad Dammam, planned to open for the 325th redeployment painting operation, not be opened until proper equipment was obtained.[141]

A memorandum written on April 28th, 1991, by a safety officer from the US Army Support Group[142] echoed the results of the 325th Al Jubayl paint site inspections of April 25-26. This memorandum cited a number of specific safety deficiencies, including:

- Inadequate drying time was allowed following paint application, representing a fire hazard;
- Hazardous waste (i.e., empty paint cans) was not segregated from regular trash;
- Personal protective equipment was not being properly worn;

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[138] Lead Sheet #20572, Interview with DoD civilian safety manager for VII Corps in theater, December 3, 1998, p. 1-2.

[139] Memorandum from Headquarters 22nd SUPCOM, for Director, 22nd SUPCOM Safety, Subject: "Chemical Agent Resistant Coating (CARC) Paint Operations, Ports of Dammam and Jubayl," April 28, 1991, p. 1-2.

[140] Memorandum from Army Materiel Command for 22nd SUPCOM Safety Officer, Subject: "Paint Operations," April 20, 1991, p. 1.

[141] Memorandum from Headquarters 22nd SUPCOM, For Director, 22nd SUPCOM Safety, Subject: "Chemical Agent Resistant Coating (CARC) Paint Operations, Ports of Dammam and Jubayl," April 28, 1991, p. 3-4.

[142] Memorandum for Record, from USASG Safety Officer, Subject: "Paint Operations," April 28, 1991, p. 1-2.

- General site control was poor, with vehicles creating dust;
- Vehicles, which had been painted with tan latex or unknown coatings, were peeling, yet were being painted over with green CARC;
- Continued pressure to increase or maintain high production numbers was creating potentially unsafe conditions.

Ultimately, the memorandum recommended that the paint operations conform to the original safety and process guidelines, including stricter standards about pre-painting preparatory work.

As a result of the April inspections of the 325th Maintenance Company's paint sites, efforts were made to further improve the safety equipment. Safety officers from the 22nd Support Command (SUPCOM) worked to obtain breathable air compressors with carbon monoxide alarms, high pressure compressors with coolers, and additional dual cartridge respirators with organic vapor and high efficiency filter cartridge combinations.[143]

A safety inspection on May 24, 1991 at the Ad Dammam CARC paint site identified several deficiencies posing a severe medical threat to the workers, including:

- Persons in or in the immediate vicinity of the painting area were not wearing the proper personal protective equipment. Respirators were worn, however, gloves and paint suits were not.
- Soldiers using solvents for cleaning tools and equipment were not wearing personal protective equipment such as respirators, rubber gloves, long sleeve shirts, and aprons.
- Soldiers were not protected from exposure to noise hazards caused by generators, compressors, and vehicle traffic.

Several recommendations were made including:

- All personnel who work in or around the paint tents need to wear proper protective equipment. Personnel must not be allowed to take the easy way out by not protecting themselves.
- Soldiers cleaning tools and other equipment with solvents must follow the recommended protective equipment procedures. They should be wearing a respirator, rubber gloves, long sleeve shirt, and an apron or other outer protective clothing;
- The chain of command must inspect soldiers before they start any hazardous job to ensure that they are properly protected. Additionally, the chain of command must immediately correct any soldier who is not following proper safety precautions.
- All noise hazards must be identified and properly marked. If possible, the hazard should be eliminated by moving the source or constructing barriers to reduce the noise hazard to a safe level. Soldiers who work near or enter a noise hazard area must wear hearing protection. Track drivers must wear hearing protection.
- Soldiers may work in a noise hazard area, provided they are fitted with hearing protection and pending baseline audiograms. Army Regulation 40-5 requires that soldiers who are

[143] Memorandum from USASG Safety Officer for 22nd SUPCOM Safety Officer, Subject: "Paint Operations," April 20, 1991, p. 1.

exposed to steady noise levels greater that 85 dBA be enrolled in a hearing conservation program.

The report concluded that the proper personal protective equipment has been made available to the soldiers. The report reiterated that it is the ultimate responsibility of unit commanders to ensure his or her soldiers are properly cared for by ensuring that they wear the required personal protective equipment (including hearing protection).[144]

On June 12, 1991, another site visit of the 325th Al Jubayl CARC site was conducted. As with the previous inspection, the inspecting officer found deficiencies in leadership and oversight that were significant enough that he felt compelled to recommend that the site be shut down immediately. Specifically, the following problems were cited at the 325th Al Jubayl paint site:

- The site safety officer and non-commissioned officer in charge were not available at the site until roughly three hours after the arrival of the inspection team;
- A copy of the standard operating procedures was not available on site;
- Several soldiers without respirators were seen near the paint tents;
- Several soldiers' paint suits were ripped;
- Soldiers were punching holes in the solvent cans using metal screwdrivers. Solvents are very flammable and a spark can cause an explosion;
- The material safety data sheets for the paint and solvent were not posted or readily available.

The inspecting officer outbriefed the senior official at the site, who stated that his unit had never been briefed or shown a copy of the standard operating procedures.[145]

E. Marine Corps Painting Operations

In the rush to deploy units to the Kuwait Theater of Operations, the Marine Corps faced many of the same hurdles as the Army. The Marine Corps attempted to acquire traditional tan CARC through the Defense Logistics Agency (DLA), but the DLA was unable to supply adequate supplies of CARC to the Marine Corps because the Army had already depleted their supplies. Marine Corps headquarters logistics offices in Quantico, Virginia, quickly located an alternate paint supplier[146] and a sole-source agreement was established with a manufacturer to provide a non-CARC, tan latex coating[147] which came in powder form and was fast, easy, and safe to apply. The powder was mixed with water, and the resultant paint was spread with a brush or roller. The temporary coating was not intended for spray gun application, and there is no

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[144] Memorandum from Department of the Army, Medical Group (Provisional) Preventive Medicine Team to Commander, SUPCOM Medical Group, Subject: Potential Medical Hazards at the Dammam Port CARC Paint Site, May 26, 1991, p. 2.

[145] Memorandum from Department of the Army Preventive Medicine Team, through Commander, SUPCOM Medical Group, Subject: "Assessment of the Al Jubayl CARC Paint Site," June 12, 1991, p. 1-2.

[146] Headquarters Marine Corps message, Subject: "Requirements for Temporary Desert Camouflage Paint," August 28, 1990.

[147] Lead Sheet #17979, Interview with Marine Corps System Command engineer, July 13, 1998, p. 1.

evidence that spray gun procedures were used.[148] Although the coatings offered the visual tan camouflage that the Marine Corps needed, they did not provide many of the other advantages offered by CARC (e.g., ease of decontamination).

Many Marine units did not have time to wait for the temporary coating to arrive. As a result, a number of Marine units in the continental US awaiting deployment to the Kuwait Theater of Operations bought tan paints locally. These coatings included household latex, alkyd paint systems, and lacquer paints. The locally-procured coatings and the non-CARC temporary coating were applied outside in open-air environments, both in the continental United States and in the Kuwait Theater of Operations. No Marine Corps vehicles were painted by the Army operations at either Ad Dammam or Al Jubayl.

Though conversations with Marine veterans have revealed no serious adverse health effects to this work, there have been reports of minor rashes experienced during the paint operations.[149] It is also important to note that the approved temporary coating used by the Marine Corps did not contain isocyanates. The use of respiratory protection for the application of the temporary coatings in these open-air environments was inconsistent, with air-purifying respirators and dust masks used in some cases, and no protection used in others.[150]

The Marine Corps redeployment policy on painting was different from the Army's. Unlike the Army, no Marine vehicles returning to the United States were painted olive drab or woodland colors before redeployment.[151] Instead, the Marine Corps waited until their vehicles had returned to the continental United States to strip and repaint them.

F. Air Force and Navy Painting Operations

The Air Force and Navy use a more common polyurethane coating. This type of coating closely resembles the high gloss coatings found on commercial aircraft. However, like the CARC used by the Army and Marine Corps, the Air Force and Navy polyurethane coatings have hexamethylene diisocyanate (HDI), found also in CARC, and a number of solvents. For this reason, the Air Force and Navy follow the same health and safety guidance that Army and Marine Corps operations follow for spray painting operations. These respiratory protection and painting procedural guidelines are part of Air Force and Navy doctrine.[152]

Many Air Force aircraft were in place prior to the air war, so there was not a significant volume of new aircraft queuing up for in-theater painting. As a result, most Air Force aircraft participating in Operation Desert Shield/Desert Storm did not require significant painting; if anything, nose, wing, and stabilizer leading edge surfaces (the front edges of the wings and tails) needed only occasional touch up work. At that level of activity, and considering the already in-place, dedicated, well-equipped painting facilities, complete with appropriate personal protective

[148] Lead Sheet #18072, Interview with USMC Master Gunnery Sergeant, July 15, 1998, p. 1.
[149] Lead Sheet #18072, Interview with USMC Master Gunnery Sergeant, July 15, 1998, p. 1.
[150] Lead Sheet #18072, Interview with USMC Master Gunnery Sergeant, July 15, 1998, p. 1.
[151] Lead Sheet #18072, Interview with USMC Master Gunnery Sergeant, July 15, 1998, p. 1.
[152] Lead Sheet #15187, Interview with Army Research Laboratory research chemist, March 8, 1999, p. 2; and Lead Sheet #27367, Interview of Navy industrial hygiene personnel, July 24, 2000.

equipment, the overall health risk to aircraft painters was low. Similarly, the Navy was limited to touch up painting of the aircraft and helicopters using long-established ship board procedures.[153]

G. Post War Guidance

As a result of the inadequate procedures being followed at the in-theater CARC painting sites, guidance regarding proper procedures was produced after the cessation of hostilities. One example was the release on May 7, 1991, of a revised standard operating procedures (SOP) for CARC painting operations. This revision had several distinct differences from the pre-war standing operating procedures for CARC operations, reflecting the growing awareness that painters in-theater were not properly trained and equipped. The revision included the following additions:

- Several new responsibilities were added for the officer in charge, including traffic pattern control and ensuring that nonessential electrical equipment was kept away from the paint area;
- New responsibilities were detailed for the site safety representative, including monitoring of wind direction, and daily check of fit and condition of respirators;
- A simple explanation was provided discussing the existence and hazards of the isocyanates within CARC;
- A description of the procedures for dealing with a fire in the CARC painting area was provided.[154, 155]

Another example of the guidance produced after the cessation of hostilities was a medical memorandum written by a physician with the 12th Preventive Medical Detachment. As the physician explained, "Due to the hazardous nature of CARC and possible danger to soldiers who apply CARC, it has become necessary to institute a more stringent protocol for monitoring individual soldiers who may come in contact with such paint."[156] The guidelines within this memorandum echo the screening requirements found in Technical Guide No. 144,[157] and contain significantly more detail than the standard operating procedures as to the pre-painting screening that should be undertaken for all potential painters. These guidelines include:

- All soldiers mixing or applying paint should be medically cleared and fit-tested for a respirator;
- Soldiers should be tested to determine baseline pulmonary function prior to donning the mask and at the end of the paint operation;
- Soldiers should be tested to determine baseline blood chemistry;

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[153] Lead Sheet #22086, Interview with Air Force bioenvironmental engineer in-theater, March 3, 1999, p. 1; and Lead Sheet #27367, Interview of Navy industrial hygiene personnel, July 24, 2000.

[154] "Standing Operating Procedures (SOP) CARC Painting Operations."

[155] "Standing Operating Procedures (SOP) CARC Painting Operations, revised copy, May 7, 1991."

[156] Memorandum from Department of the Army Medical Group (Provisional) Preventative Medicine Team to Commander, Medical Group (Provisional), Subject: "Physical Examinations and Medical Monitoring of Troops Conducting CARC Painting Operations," May 28, 1991, p. 1.

[157] A discussion of the requirements found in "Guidelines for Controlling Health Hazards in Painting Operations," Technical Guide 144, is found in this report in Section III. Description of CARC and Tab E., Occupational Safety and Health Guidance.

- Soldiers who fail to follow any of the protective procedures should be re-educated about the potential dangers.[158]

A command surgeon from VII Corps generated further guidance concerning health and safety at CARC paint sites. This memorandum discussed field sanitation responsibilities, hearing conservation requirements, vision protection, and painter safety equipment. It also went into detail on the roles and responsibilities of the safety manager and the need for medical surveillance, including proper screening and physical exams. Attached to the memo was a sample history and physical examination screening form. The form lists standard steps that a physician can use to screen a soldier for eligibility to work with paint.[159]

[158] Memorandum from Department of the Army Medical Group (Provisional) Preventive Medicine Team to Commander, Medical Group (Provisional), Subject: "Physical Examinations and Medical Monitoring of Troops Conducting CARC Painting Operations," May 28, 1991, p. 1-2.

[159] Memorandum from Headquarters, VII Corps Redeployment Command, to Commander, VII Corps Redeployment Command, Subject: "Health and Safety Recommendations for CARC Painting Sites," June 4, 1991.

V. MEDICAL FOLLOW-UP OF THE 325th MAINTENANCE COMPANY

Following their service in the Gulf War, the 325th Maintenance Company returned to Florida. As previously discussed, a number of soldiers from the unit experienced health problems while in Saudi Arabia. In many cases, these health problems persisted or even intensified after their return home. As a result of the large number of health problems experienced by the deployed 325th members and veterans, health testing was conducted while the unit was conducting its two-week annual training at Ft. Stewart, Georgia, in 1992. An Army occupational medicine physician from Florida examined members of the 325th. He reported skin rashes in 10 to 15 soldiers, as well as a number of cases of non-specific symptoms, such as headaches, fatigue, and sleep difficulty. The physician was also able to perform pulmonary function tests on 20 to 30 soldiers from the unit. He recalls asthma-like symptoms in a number of these soldiers, many of whom complained of recurring breathing difficulties. He also noted that he saw symptoms consistent with possible chemical sensitization from CARC exposure in some of the soldiers.[160] Due to the numerous health complaints within the unit, all Gulf War veterans still in the unit were given several other medical tests, including blood tests, while at Ft. Stewart.[161]

Some soldiers from the 325th Maintenance Company communicated their CARC painting experiences to their US representative, Charles Canady of Florida's 12th District. A series of correspondence between the congressman and DoD officials discussed the issues of CARC exposures and medical care and post-deployment support provided to Operation Desert Storm National Guard members.[162,163] The matter was referred to the National Guard Bureau (the top echelon of the National Guard) for investigation.[164] The National Guard Bureau Inspector General issued an assessment addressing health care issues for veterans of Operations Desert Shield and Desert Storm in June 1994.[165]

The House of Representatives' Committee on Veterans' Affairs held a hearing regarding Gulf War veterans' issues on June 9, 1993. Major General Robert Ensslin, Jr., adjutant general for the state of Florida responsible for the mobilization, deployment, and demobilization of the 325th, delivered a statement regarding the 325th Maintenance Company. In his statement MG Ensslin noted that over 200 Army National Guard members were released from active duty who had not completed medical treatment for duty related injuries or illnesses. Although this action to expedite the return of soldiers to their home station was well intended, many National Guardmembers had difficulty in receiving treatment once discharged, since their Gulf War-

[160] Lead Sheet #15654, Interview with Occupational medicine physician at Fort Stewart, March 31, 1998, p. 1.
[161] Lead Sheet #15190, Interview with 325th Maintenance Company painter, January 4, 1999, p. 2; Lead Sheet #21081, Interview with 325th Maintenance Company painter, January 13, 1999, p. 2.
[162] Letter from Charles T. Canady, Congress of the United States, House of Representatives, April 27, 1993.
[163] Letter from Charles T. Canady, Congress of the United States, House of Representatives, May 28, 1993.
[164] Letter from Lt. Gen. John B. Conaway, National Guard Bureau, May 20, 1993.
[165] Memorandum from the National Guard Bureau for Acting Chief, National Guard Bureau, Subject: "NGB-IG Assessment of Patient Administration and Health Care for National Guard Desert Storm/Shield Veterans—Action Memorandum," June 30, 1994.

related exposures or related symptoms had not been reported, evaluated, treated, or documented.[166]

On October 9, 1996, the issue of the 325th Maintenance Company's exposure to CARC was discussed at a Presidential Advisory Committee on Gulf War Veterans' Illnesses (PAC) hearing. The PAC was established in May 1995 to ensure independent, open, and comprehensive examination of health concerns related to Gulf War service.[167] At the hearing, a representative from the Florida Department of Veterans' Affairs and a member of the 325th Maintenance Company provided statements. Both speakers explained that a number of veterans from the 325th had become ill due to their work with CARC. They also described some of the difficulties that veterans faced in obtaining treatment and benefits for their illnesses.[168]

As with members of active Army units, National Guard members in units like the 325th can pursue health care through the DoD's Comprehensive Clinical Evaluation Program (CCEP).[169] However, unlike active Army servicemembers, National Guard (and Reserve) members are not paid when they miss duty unless a doctor states that they are incapacitated and unable to perform their duty. For a Gulf War veteran to receive disability and medical treatment through the Comprehensive Clinical Evaluation Program, participation in Phase I of the program is required. This involves undergoing a free medical evaluation. If a physician diagnoses a health problem, an evaluation can then be made as to whether the illness is connected to a soldier's Gulf War service, called a "line of duty" determination.[170] Though Guard members are reimbursed for their travel expenses to go to a DoD or VA clinic to receive their Phase I medical evaluation (i.e., mileage, lodging, food), they are not reimbursed or compensated for time off from their civilian jobs, which in many cases imposes a financial hardship on deployment veterans and their families. Additionally, establishing the line of duty status for an illness does not necessarily guarantee compensation or benefits. Veterans only receive compensation if they are unable to perform their assigned duty or their military occupational specialty. Conversations with a specialist working with the CCEP revealed that Guard members often do not avail themselves of the CCEP evaluation process because of the monetary cost of taking the time off from their civilian jobs, as well as their skepticism that they will ever receive line of duty compensation.[171]

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[166] Testimony of Maj. Gen. Robert F. Ensslin, Jr. before the Subcommittee on Oversight Investigations of the Committee on Veterans' Affairs, House of Representatives, June 9, 1993, p. 282.

[167] Final Report of the Presidential Advisory Committee (PAC) on Gulf War Veteran's Illnesses, Washington, DC: US Government Printing Office, December 1996, Executive Summary p.1. web site www.gwvi.ncr.gov/exsumm-f.html (as of January 21, 1999)

[168] Testimony of Mr. Tim Ivories and Mr. William Carpenter before the Presidential Advisory Committee (PAC), October 9, 1996, web site www.gwvi.ncr.gov/1009gulf.html (as of January 21, 1999).

[169] The DOD's Comprehensive Clinical Evaluation Program (CCEP) is available to all Gulf War veterans currently on active duty, active in the Reserves or National Guard, or retired from the military. The program begins with an in-depth medical evaluation.

[170] Current National Guardmembers in the 325th Maintenance Company must first register in the CCEP and complete Phase I before a line of duty (LOD) investigation can begin. LOD investigations are then managed by the Headquarters of the Florida National Guard and are sent to the National Guard Bureau for determination of line of duty status.

[171] Lead Sheet #21390, Interview with Florida National Guard personnel representative, February 2, 1999, p. 1-2.

A number of Guardsmen who served with the 325th Maintenance Company during Operation Desert Shield/Storm left the National Guard and returned to civilian life at some point after the war. Unlike those who remained in the unit, these former Guardsmen are not eligible for the DoD's CCEP program. Instead, they can enroll in the Department of Veteran's Affairs (VA) Persian Gulf Registry[172] to receive medical evaluation. Due to the large number of soldiers in the 325th who were experiencing health problems, Veterans Affairs staff made a number of visits to the unit's headquarters in Lake Wales, Florida, between 1992 and 1993. The VA representatives were also on hand at the unit's annual training at Ft. Stewart shortly after their return from Saudi Arabia.[173] Over 100 claims from the 325th have been processed. Through this program, several members of the 325th have been discharged and given compensation and benefits for disabilities that were associated with their wartime service.[174]

As of October 1999, 66 members of the 325th Maintenance Company had received CCEP medical evaluations, and 97 members had received VA Persian Gulf Registry evaluations. Since there were about 200 members of the 325th who performed painting operations, a high proportion have enrolled in the two registries. At the start of the Gulf War in 1990, these 163 soldiers ranged in age from 19 to 58 years.

Seventy of the 163 soldiers had a diagnosis or symptoms of a respiratory disease, including 10 diagnosed with asthma. Asthma is the most specific type of chronic effect that would be expected after long-term exposure to isocyanates. Generally, in other populations, this disease has developed in workers who have been exposed for at least 12 months to several years.[175]

Several members of the 325th have been awarded compensation for disability due to a variety of service-connected diseases. Because the complete medical and compensation records could not be reviewed due to privacy act considerations, the particular disabling conditions for which these veterans were compensated have not been disclosed to OSAGWI investigators. The CCEP and VA Persian Gulf Registry databases do not provide information about changes in diagnoses over time, ongoing treatment, or disability determinations within the DoD or VA health care and benefit systems.

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[172] The Department of Veterans Affairs Persian Gulf War Registry is for Gulf War veterans not currently on active duty. It begins with a free, complete physical examination with basic laboratory studies.

[173] Lead Sheet #21390, Interview with Florida National Guard personnel representative, February 2, 1999, p. 2.

[174] Lead Sheet #14336, Interview with Executive Director of the Florida Department of Veterans Affairs, February 11, 1998, p. 1.

[175] Banks, D.E., "Respiratory Effects of Isocyanates," Environmental and Occupational Medicine, 1998, p. 542.

VI. CONCLUSIONS

An estimated 200 soldiers from the 325th Maintenance Company and an unknown number of soldiers from smaller paint operations were potentially exposed to the hazards of CARC during spray painting operations during Operations Desert Shield and Desert Storm. These exposures occurred primarily due to the tasking of ill-equipped, poorly trained, and inexperienced service members to operate the two main spray painting operations in the Saudi Arabian ports of Ad Dammam and Al Jubayl. Despite repeated health and safety inspections over a seven-month period (December 1990 – June 1991) that identified serious risks, hazards, and deficiencies, painting activities continued at these two facilities with only limited improvements.

The principal health threat associated with CARC is hexamethylene diisocyanate (HDI) and various solvents used in the spray painting process. Due to the lack of adequate personal protection, and a larger failure to adhere to applicable safety and occupational health policies and procedures, a number of soldiers directly involved in CARC painting may have suffered adverse health effects, primarily respiratory effects from exposures to HDI and solvents. However, this investigation cannot definitively link CARC painting operations to the undiagnosed illnesses reported by Gulf War veterans, except in a small number of cases involving a limited number of personnel, where soldiers were known to have been directly involved in painting operations.

Several recommendations for improvements in the policy regarding minimizing exposures to CARC paint during future deployments are identified in the lessons learned section.

VII. LESSONS LEARNED

The Gulf War brought on a heightened awareness of "dirty battlefield" hazards and their impact on the health and readiness of deployed forces. In the aftermath of the conflict, retrospective investigations and analyses, including this one, have identified deficiencies and gaps in the way the Department of Defense and the Services recognized and responded to non-traditional or unanticipated risk factors. This awareness has in turn produced a major new emphasis on improving medical readiness and force health protection policies, programs, procedures, and guidance aimed at protecting the health and safety of deployed US personnel.

The following section contains a number of important lessons developed during the investigation of CARC painting performed in the Kuwait Theater of Operations (KTO). Where appropriate, the Office of the Special Assistant recommends the following courses of action to address the noted shortcomings.

Pre-deployment Painting

We determined that pre-deployment and post-deployment CARC-painting operations outside of the KTO were outside the scope of our investigation, although these deployment-related practices require further assessment by the relevant DoD occupational health and safety offices.

During our investigation of paint operations in the Gulf War theater, some soldiers reported that a number of standard procedures, including painting vehicles with CARC, were modified (or disregarded) in the rush to mobilize troops and equipment for Operations Desert Shield and Desert Storm. In some cases, safety considerations were compromised. In the future, military operational plans and policies should anticipate similar requirements, and be prepared to meet them without compromising occupational safety and health standards. Prior planning should improve the military's ability to quickly establish field-expedient, but safe, CARC painting sites. Advance training, education, and guidance should raise the level of awareness of potential hazards involved when painting with CARC. The CARC-painting mission should be assigned to appropriate units before deployment—units that could obtain the required procedural and safety training, procure personal protective equipment, and ensure direct oversight and guidance by trained, certified, experienced safety and occupational health professionals who have the command authority and support to ensure that operations are conducted in accordance with the applicable health and safety policies and procedures.

Painting In Theater

In general, US troops tasked to spray paint vehicles in-theater lacked the training, education, guidance, and oversight needed to ensure safe and successful mission accomplishment In addition, despite repeated warnings from health and safety specialists in-theater, tactical commanders charged with directing the CARC paint effort did not fully appreciate the hazards associated with spray painting CARC, or safeguard their health and wellness while still accomplishing their mission. In the future, CARC painting requirements should be more fully developed during pre-operation planning. Advance planning would enable commanders to

assign the mission to appropriate units and personnel prior to deployment. The assigned units could obtain the required occupational safety and health training, procure personal protective equipment and the other materiel needed to perform their duties in a safe and efficient manner.

Recent guidance from the DoD and Joint Chiefs of Staff, along with implementing Service guidance, respond to these requirements. Service members with assigned duties requiring occupational health-related personal protective equipment are now required to deploy with appropriate personal protective equipment (respiratory protection, hearing protection, and personal exposure dosimeters).[176]

Medical Screening

The lack of pre-deployment planning prevented appropriate pre-deployment occupational health screening of members of the 325th Maintenance Company. Even if medical screening could not have been completed prior to deployment, properly trained leaders and soldiers would have known about the hazards of CARC painting and the need for medical screening before and during the painting operations. In addition, they could have identified a requirement for post-deployment occupational health screening. The purpose of medical surveillance is to detect any adverse health effects based on the specific hazards to which personnel are exposed.

Post-deployment occupational health evaluations prior to separation from active duty could have identified many of the problems encountered by members of the 325th Maintenance Company. Follow-up medical care decisions may have been more timely for those veterans. To remedy this situation, the services should develop procedures to identify target populations at risk (e.g., CARC painters), and ensure that appropriate post-deployment occupational health evaluations are administered in a timely manner.

Since the Gulf War, the Department of Defense has addressed the post-deployment issue. DD Form 2697, Report of Medical Assessment, November 1995,[177] is now required as a minimum to provide a comprehensive medical assessment of active and reserve members who are separating or retiring from active duty. It is intended to serve as a medical history that will trigger further medical follow-up if the servicemember reports an unusual exposure, has health problems or concerns, or plans to file for disability.

Redeployment Painting Operations

The redeployment painting operations conducted in-theater were more mature than were the operations initially established for tan painting, however, routine safety inspections continued to document numerous problems. Occupational Safety and Health Administration (OSHA) regulations do not apply during actual combat. However, redeployment operations should strictly adhere to OSHA regulations.

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[176] Memorandum from the Joint Chiefs of Staff to Under Secretary of Defense for Personnel and Readiness, et. al., Subject: "Deployment Health Surveillance and Readiness," December 4, 1998, p. 3.
[177] DD Form 2697, Report of Medical Assessment, November 1995.

In addition, paint surfaces received only minimal preparation, generally washing with water, before applying green CARC. Like the tan coatings applied several months earlier, these green coatings often began to peel after a short time. As a result of redeployment painting operations, some painters were needlessly put at risk to the hazards of spray painting for a paint coating that would most likely need to be reaccomplisheed in a more satisfactory fashion a short time later.

Recommended Steps to Reduce Potential Exposures During CARC Painting Operations

Potential exposures of soldiers spray-painting CARC could be decreased by:

- Painting the vehicles at home station. This would leverage the availability of proper personal protective equipment, trained personnel, and paint facilities existing at military installations and bases, and would be done in accordance with peacetime, regulatory safety and occupational health policies and procedures;
- Assigning trained personnel to establish and oversee paint operations in advance of redeployment. Trained personnel would ensure that the proper personal protective equipment was on hand before the painting operations commenced and the proper protocols were followed.
- Designating a unit with a wartime mission to conduct large-scale painting operations. This practice is followed with other specialized requirements. It would also be appropriate for painting operations where there is a requirement for specialized training and equipment that could be mobilized with the team and deployed anywhere in the world.
- Developing alternative CARC paint formulations. This could include reducing the levels of solvents, developing water-based CARC, and reducing the levels of HDI.
- Developing standardized equipment packages for various missions options.
  - Developing augmentation sets that include all the personal protective equipment, tents, explosive proof lighting/electrical outlets, training materials, etc. for CARC painting operations. The augmentation sets could be placed in operational project stocks.
  - Type-classifying sets, kits and outfits that include all the personal protective equipment, tents, explosive proof lighting/electrical outlets, training materials, etc. for CARC painting operations for inclusion in appropriate maintenance units authorized equipment list (Table of Organization and Equipment).
- Holding commanders accountable for the health and safety of their troops; for taking appropriate action to provide necessary training; for obtaining appropriate safety equipment, and ensuring that the safety equipment is used and maintained as required; and for taking immediate steps to resolve any identified safety and health deficiencies.

Efforts to Implement Lessons Learned

Lessons Learned are loosely classified as either systemic or individual failures. The problems associated with CARC painting operations in the Gulf were primarily attributable to individual or leadership failure to ensure that well-established health and safety guidelines associated with

isocyanate painting operations were followed. Health and safety inspections repeatedly identified the problems, but corrective actions, when taken, were often short-lived.

The primary focus of our efforts to ensure that the lessons learned in the Gulf War are integrated into the Army's future planning (since the Army has the largest requirement for CARC paint operations). Our vehicle to facilitate the implementation (and institutionalization) of needed improvements has been a series of reviews conducted through the US Army Training and Doctrine Command's Campaign Plan Undersecretary of the Army. These force health development reviews analyze issues such as the problems with CARC painting across existing doctrine, organization, training, leadership development, material development, and policy domains to effect the needed changes. CARC is one of several issues being addressed in this manner.

In addition, we have coordinated our findings and recommendations with the applicable DoD offices, such as the Deputy Under Secretary of Defense for Environmental Security; the Office of the Assistant Secretary of Defense for Health Affairs; the National Guard Bureau; Joint Staff Deputy Director for Medical Readiness who coordinated with the Offices of the Army, Navy and Air Force Surgeons General; the US Army's Center for Health Promotion and Preventative Medicine; the US Army Research Laboratory (Polymers Research Branch); and the Federal Occupational Safety and Health Administration

As often cited, "those who cannot remember the past are condemned to repeat it." Therefore, our emphasis has been to inform and educate DoD's leadership on the hazards of CARC painting operations and the procedures needed to protect the health of our soldiers, sailors, and airmen.

If you have records, photographs, or first-hand knowledge and information regarding the events and activities described in this report, or can offer corrections or pertinent details, please call 1-800-497-6261.

TAB A – Acronyms, Abbreviations, and Glossary

This TAB provides a listing of acronyms found in this report. Additionally, the Glossary section provides definitions for selected technical terms that are not found in common usage.

Acronyms and Abbreviations

AAD ..... Anniston Army Depot
AAR ..... after action report
ACGIH ..... American Conference of Governmental Industrial Hygienists
ACR ..... armored cavalry regiment
AMC ..... Army Materiel Command
ARCENT ..... Army Central Command
ARL ..... Army Research Lab
ASAP ..... as soon as possible
ASG ..... area support group
CARC ..... chemical agent resistant coating
CCEP ..... Comprehensive Clinical Evaluation Program
CFR ..... Code of Federal Regulations
CHPPM ..... Center for Health Promotion and Preventive Medicine
CINCFOR ..... Commander in Chief, Forces Command
CINCUSAREUR ..... Commander in Chief, United States Army Europe
CNS ..... central nervous system
CO ..... carbon monoxide
COPD ..... chronic obstructive pulmonary disease
CSC ..... convoy support center
CWA ..... chemical warfare agent
DA ..... Department of the Army
DBA ..... decibels, A-scale
DESCOM ..... United States Army Depot Systems Command
DHHS ..... Department of Health and Human Services
DLA ..... Defense Logistics Agency
DoD ..... Department of Defense
DS2 ..... decontaminating solution number 2
EPA ..... Environmental Protection Agency
FSTV ..... fire support team vehicle
HDI ..... hexamethylene diisocyanate
HMMWV ..... high mobility multi-wheeled vehicles
hp ..... horsepower
IG ..... inspector general
KKMC ..... King Khalid Military City
KTO ..... Kuwait theater of operations
lbs ..... pounds
LNO ..... liaison officer
LEL ..... lower explosive (flammable) level in air

LOD ..... line of duty
LTG ..... lieutenant general
MDI ..... methylene diisocyanate
MEB ..... Marine expeditionary brigade
MIL SPEC ..... military specification
MG ..... major general
mg/m^3 ..... milligrams per cubic meter
MOPP ..... mission oriented protective posture
MOS ..... military occupational specialty
MSDS ..... material safety data sheet
NCOIC ..... non-commissioned officer in charge
NGB ..... National Guard Bureau
NIOSH ..... National Institute for Occupation Safety and Health
ODS/DS ..... Operation Desert Shield/Desert Storm
OIC ..... officer in charge
OSHA ..... Occupational Safety and Health Administration
PAC ..... Presidential Advisory Committee
PEL ..... permissible exposure level
PPE ..... personal protective equipment
PPM ..... parts per million
PSA ..... port support authority
PSI ..... pounds per square inch
QPL ..... qualified products list
REL ..... recommended exposure level
SITREP ..... situation report
SOP ..... standard operating procedures
STEL ..... short-term exposure limit
SUPCOM ..... support command
TAA ..... tactical assembly area
TF ..... task force
TLV ..... threshold limit value
USAEHA ..... United States Army Environmental Hygiene Agency
USASG ..... United States Army Support Group
USMC ..... United States Marine Corps
VA ..... Department of Veteran Affairs
VOC ..... volatile organic compound

Glossary

Acute health effect:	An undesirable symptom or set of symptoms that is immediate and short-term.
Aerosolization:	To bring a substance to a gaseous suspension of fine solid or liquid particles, such as with spraying paint.
Air-purifying respirator:	A negative-pressure mask that uses filter cartridges to clean air for the user. The type of filter cartridge required varies based upon the expected contaminant.
Air-supplied respirator:	A positive-pressure mask that takes in air through a hose. The air is provided by a powered compressor and exits the mask through vents.
Antigen:	A substance that when introduced into the body stimulates the production of an antibody. Antigens include toxins, bacteria, and foreign blood cells.
Asthma:	Chronic respiratory system disorder characterized by wheezing, coughing, and difficulty in breathing.
Bronchitis:	An inflammation of the mucous lining of the bronchial tubes, which often causes coughing and sputum production.
Carbon monoxide:	A colorless, odorless, highly poisonous gas, CO, formed by the incomplete combustion of carbon or a carbonaceous material, such as gasoline or oil in compressors.
Carcinogenic:	A compound or material capable of causing cancer.
Chemical bronchitis:	An inflammation of the mucous lining of the bronchial tubes brought on by exposure to an irritant substance.
Chemical sensitization:	An individual who is hypersensitive or reactive to an antigen (e.g., toxins), especially through a second or repeated exposure. Also characterized as an allergic reaction to a chemical. Individuals spraying CARC without proper respiratory protection are at risk of chemical sensitization to hexamethylene diisocyanate (HDI).
Chronic health effect:	An undesirable symptom or set of symptoms lasting a long period of time or marked by frequent recurrence.

Cooling vortex:	An apparatus, used with some air-supplied respirators, that cools the air flowing into a respirator and paint suit. This improves the working conditions for a painter in a hot environment.
dBA:	Unit of measure of sound measured on a sound level meter using the A-weighted network with slow meter response.
Hexamethylene diisocyanate (HDI):	A low-molecular-weight compound used in CARC as a resin to aid in the formation of the polyurethane.
Hypersensitivity pneumonitis:	A condition in which lung tissue is highly sensitive and easily inflamed by certain stressors. This is a type of chronic pneumonia caused by a chemical or microorganism.
In-theater:	Occurring in the Kuwait theater of operations.
Monomer:	A simple molecule that can form polymers by combining identical or similar molecules
Occupational asthma:	Variable airflow limitation due to causes and conditions that are attributable to a particular occupational environment, and not to stimuli outside the workplace.
Oligomer:	See prepolymer
Organic vapor:	The gaseous state of a carbon-based compound.
Personal protective equipment:	A variety of equipment, such as respirators, gloves, and coveralls, that are designed to protect an individual from a known hazard.
Polymer:	A naturally occurring or synthetic substance consisting of giant molecules formed from smaller molecules of the same substance and often having a definite arrangement of the components of the giant molecules
Positive pressure respirator:	An air-supplied or powered air-purifying mask in which the pressure inside the mask is higher than the outside environment. Clean, supplied air constantly flows into the mask from an air hose for inhalation, while exhaled air exits the mask through vents.
Prepolymer:	An intermediate building block of molecules eventually forming a polymer. Also called an oligomer.

Pre-filter:	A device used with an air-supplied respirator that prevents large particulate matter and debris from entering an individual's mask.
Pulmonary function test:	A test performed to assess the lung strength and lung capacity of an individual. One use of this test is to screen and provide a baseline for individuals who will be wearing a respirator.
Raw material:	An unprocessed natural substance used in manufacturing.
Reflectance properties:	A characteristic of a material that refers to its ability to reflect certain wavelengths of radiation (e.g., light). Many CARCs have the characteristic of mimicking reflectance properties found in nature, thereby increasing the ability of equipment to evade enemy infrared detection.

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TAB C – CARC Paint Specifications and Formulations

C. Technical Specifications

1. Military Specifications

All color variations of CARC must meet stringent military specifications. The typical formulation of these finishes consists of three primary groups of raw materials: the resin or binder system, the pigment package, and the solvents.

As a means of standardizing the paint formulations manufactured by private contractors for the military, the system of military specifications (MIL SPEC) is used. The military specification lists all the requirements of the paint, which describes types and composition of materials, color and spectral reflectance properties, and label markings.

One of these military specifications, MIL-C-46168 specifies a two-component system and references nineteen colors, including Tan 686A. The specification is available in two types, type II and type IV. Type II is the older version with a standard amount of volatile organic compounds (VOC). Type IV is a modified formula that has a reduced VOC content of up to 3.5 pounds per gallon or 420 grams per liter.[178] Volatile organic compounds can be an occupational health hazard, as well as an environmental concern. VOCs react with the atmosphere, resulting in the production of air pollutants that are components of smog. Volatile organic compounds are also a source of occupational health hazards.

The other topcoat specification is MIL-C-53039, a single component system. MIL-C-53039 references nineteen colors with Tan 686A as one its colors. This specification has only one type and has a VOC content that does not exceed 3.5 pounds per gallon or 420 grams per liter.[179] Both the two-component and one-component paint systems were used in theater.[180] See Tab D for a chart showing the different colors and variations of CARC used in theater.

2. Qualified Products List

The military uses the qualified products list as another control measure to ensure the consistency, quality, and performance of its paints. The qualified products list (QPL) is a list of approved suppliers. The Army Research Laboratory has rigorously tested the products of the manufacturers listed on the QPL for conformance to all specifications of performance and composition. Only products from suppliers listed on the QPL are normally procured for use on government material.[181]

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[178] Military Specification, Coating, Aliphatic Polyurethane, Chemical Agent Resistant, MIL-C-46168D(ME), May 21, 1987, p. 2.

[179] Military Specification, Coating, Aliphatic Polyurethane, Chemical Agent Resistant, MIL-C-53039A(ME), November 23, 1988, p. 9.

[180] Material safety data sheet taken off a paint can in theater, 686 Tan, Type II, MIL-C-46168D; Lead Sheet #21577, Notes from watching video of paint site inspections taken by 22nd Support Command safety officer, February 5, 1999, p. 1.

[181] Lead Sheet # 15187, Interview with Army Research Laboratory research chemist, August 9, 1999, p. 4.

B. CARC Paint Formulations

The resin systems used in the Army's camouflage coatings are polyureas and polyurethane-type materials. The pigments can be a variety of colors and provide the low-gloss properties as well as color to the paint. The solvents used are generally standard hydrocarbon-based materials that assist in package viscosity and spraying properties. The following formulations are representative of two component, or MIL-C-46168, camouflage coatings, and list the major ingredients found in these paints. Note that the formulations for the tan and green coatings are very similar, with the principle differences residing in the pigments. (Note: Information provided by US Army Research Laboratory.)

As discussed in this report, Tan 686 was used initially in the Kuwait theater of operations. A modified version of this paint, Tan 686A, was later used due to its ability to reduce the amount of solar heat vehicles would absorb. Green 383 was used during the redeployment painting operation. Figure 11 shows the different variations of the CARCs used in theater. Note that there is a two component and one component version of each paint, both of which were used in theater. Also, there were two different types of the two component paint used, Type II and Type IV.

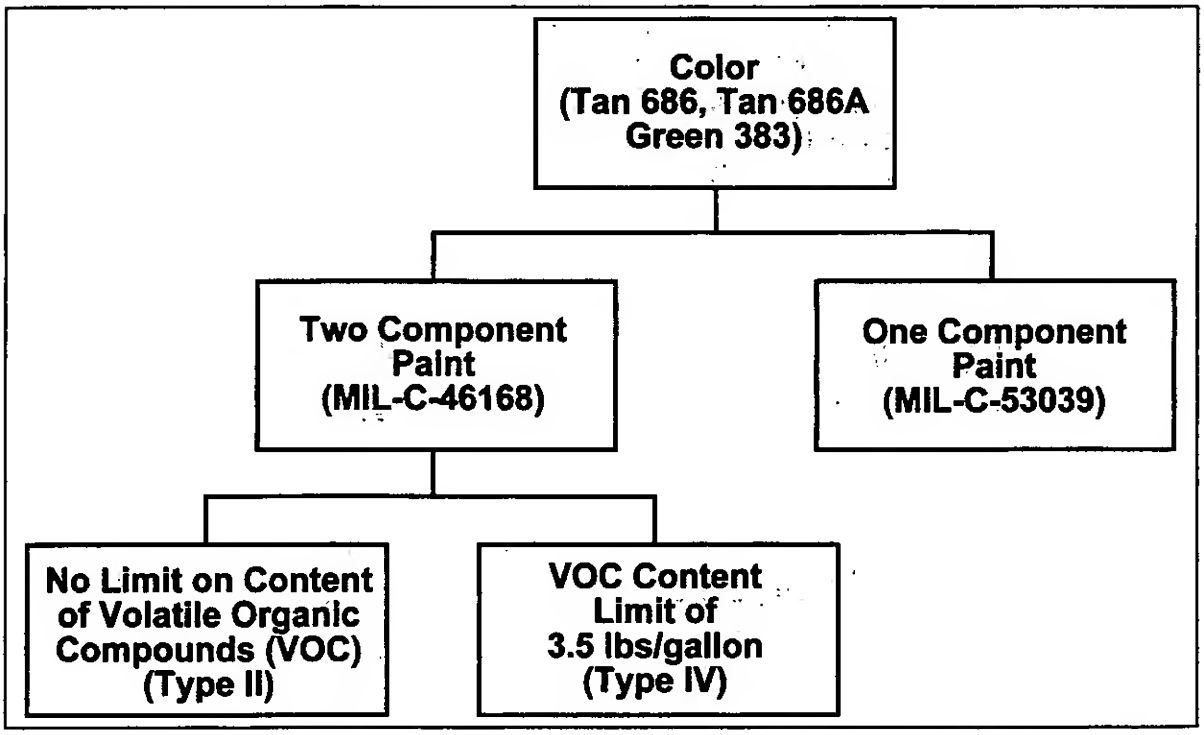

Figure 11. CARC variations used in-theater

1. Tan 686A, two-component coating:

- Part A

Resins: Polyester, Bayer Desmophen 650A/65
Polyester, Bayer Multron R221/75

Pigments: Titanium dioxide - imparts color
Yellow iron oxide - imparts color
Chrome oxide - imparts color
Carbazole violet - imparts color
Silica - flattening agent
Diatomaceous silica - flattening agent

Solvents: Methyl isoamyl ketone (MIAK) - viscosity and spray properties
Methoxypropanol acetate (PM Acetate) - viscosity and spray properties
Xylene - viscosity and spray properties
Aromatic 100 - spray properties

- Part B

Resin: Hexamethylene diisocyanate (HDI), Bayer Desmodur N751

Solvent: N-Butyl acetate - viscosity and spray properties

2. Green 383, two-component coating:

- Part A

Resins: Polyester, Bayer Desmophen 650A/65
Polyester, Bayer Multron R221/75

Pigments: Chrome oxide - imparts color
Cobalt – chrome green, - imparts color
Magnesium ferrite - imparts color
Carbazole dioxazine - imparts color
Silica - flattening agent
Diatomaceous silica - flattening agent

Solvents: Methyl isoamyl ketone (MIAK) - viscosity and spray properties
Methoxypropanol acetate (PM acetate) - viscosity and spray properties
Xylene - viscosity and spray properties
Aromatic 100 - spray properties

- Part B

Resin: Hexamethylene diisocyanate (HDI), Bayer Desmodur N751

Solvent: N-Butyl acetate - viscosity and spray properties

TAB D – Examples of Solvents Contained in CARC and Paint Thinner Used During Operations Desert Shield and Desert Storm

Solvents (CAS #)	% by Weight	LEL (%)[1]	PEL/REL/TLV[2]	IDLH (ppm)[3]	Odor Characteristics	Short-Term Health Effects	Long-Term Health Effects	Target Organs
MIL-C-46168D, Tan 686 CARC, Part A								
PM Acetate (108-65-6)	2	1.7	TLV not established			Irritant; Cough; Dizziness; Drowsiness; Headache; Nausea; Sore throat; Dry skin. Irritates eyes and respiratory tract. Exposure at high level may result in central nervous system depression.	Defats skin.	Eyes, skin, respiratory system, central nervous system.
Butyl Acetate (123-86-4)	6	1.7	PEL: TWA 150 ppm TLV: TWA 150 ppm	1700 ppm	Strong fruity odor	Irritant; Headache; Drowsiness; Narcosis; Irritates the eyes and respiratory tract. Exposures far above PEL could cause lowering of consciousness.	Defats skin	Eyes, skin, respiratory system, central nervous system
Methyl Propyl Ketone (107-87-9)	2	1.5	PEL: TWA 200 ppm TLV: TWA 200 ppm	1500 ppm	Fruity, ethereal odor	Irritates eyes, skin and respiratory tract. Exposures above PEL could cause lowering of consciousness.	Repeated or prolonged contact with skin may cause dermatitis.	Eyes, skin, respiratory system, central nervous system
Methyl Ethyl Ketone (78-93-3)	2	1.4 (200°F)	PEL: TWA 200 ppm TLV: TWA 200 ppm	3000 ppm	Acetone-like odor	Irritant; Headache; Dizziness; Vomiting; Dermatitis; The substance irritates the eyes and respiratory tract. May cause effects on the CNS. Exposure far above the PEL may result in unconsciousness.	Defats skin; Animal tests show that this substance possibly causes toxic effects upon human reproduction.	Eyes, skin, respiratory system, central nervous system
MIL-C-46168, Part B								
Xylene (1330-20-7)	12.5		PEL: TWA 100 ppm TLV: TWA 100 ppm			Irritant		
n-Butyl Acetate (123-86-4)	12.5	1.7	PEL: TWA 150 ppm TLV: TWA 150 ppm	1700 ppm	Strong fruity odor	Irritant; Headache; Drowsiness; Narcosis; Irritates the eyes and respiratory tract. Exposures	Defats skin	Eyes, skin, respiratory system, central nervous system

Solvents (CAS #)	% by Weight	LEL (%)[1]	PEL/REL/TLV[2]	IDLH (ppm)[3]	Odor Characteristics	Short-Term Health Effects	Long-Term Health Effects	Target Organs
						far above PEL could cause lowering of consciousness.		
MIL-C-46168D Type II, 383 Green								
Toluene (108-88-3)	<10	1.1	TWA 200ppm, Ceiling 300 ppm, 10-minute maximum peak - 500 ppm REL: TWA 100ppm TLV: TWA 50 ppm (skin)	500 ppm	Benzol-like odor	Irritates the eyes and respiratory tract. Exposure could cause CNS depression. Exposure at high levels may result in cardiac dysrhythmia, unconsciousness and death.	Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the CNS resulting in decreased learning ability and psychological disorders. Animal tests show that this substance possibly causes toxic effects upon human reproduction.	Eyes, skin, respiratory system, central nervous system, liver, kidney
Xylene (1330-20-7)	<10		PEL: TWA 100 ppm TLV: TWA 100 ppm			Irritant		
1-Methoxy 2-Propanol Acetate (108-65-6)	20-30							
Methyl Ethyl Ketone (78-93-3)	<10	1.4 (200°F)	PEL: TWA 200 ppm TLV: TWA 200 ppm	3000 ppm	Acetone-like odor	Irritant; Headache; Dizziness; Vomiting; Dermatitis; The substance irritates the eyes and respiratory tract. May cause effects on the CNS. Exposure far above the PEL may result in unconsciousness.	Defats skin; Animal tests show that this substance possibly causes toxic effects upon human reproduction.	Eyes, skin, respiratory system, central nervous system
MIL-C-53039A, Green 383								
Methyl Isoamyl Ketone (110-12-3)	29.69	1.0 (200°F)	PEL: TWA 50 ppm TLV: TWA 50 ppm		Pleasant odor	Irritates the eyes, skin and respiratory tract. The substance may cause effects on the kidneys, resulting in kidney impairment.	Repeated or prolonged contact with skin may cause dermatitis.	Eyes, skin, respiratory system, central nervous system, liver, kidney

Solvents (CAS #)	% by Weight	LEL (%)[1]	PEL/REL/TLV[2]	IDLH (ppm)[3]	Odor Characteristics	Short-Term Health Effects	Long-Term Health Effects	Target Organs
						Exposure above PEL could cause lowering of consciousness.		
Butyl Acetate (123-86-4)	1.24	1.7	PEL: TWA 150 ppm TLV: TWA 150 ppm	1700 ppm	Strong fruity odor	Irritant; Headache; Drowsiness; Narcosis; Irritates the eyes and respiratory tract. Exposures far above PEL could cause lowering of consciousness.	Defats skin	Eyes, skin, respiratory system, central nervous system
MIL-C-53039A, Tan 686A								
Methyl-Isoamyl Ketone (110-12-3)	20-30	1.0 (200°F)	PEL: TWA 50 ppm TLV: TWA 50 ppm		Pleasant odor	Irritates the eyes, skin and respiratory tract. The substance may cause effects on the kidneys, resulting in kidney impairment. Exposure above PEL could cause lowering of consciousness.	Repeated or prolonged contact with skin may cause dermatitis.	Eyes, skin, respiratory system, central nervous system, liver, kidney
Methyl Isobutyl Ketone (108-10-1)	6.26	1.2 (200°F)	PEL: 50 ppm TLV: 50 ppm	500 ppm	Ethereal odor	Irritant; Narcotic in high concentrations; Headache; narcosis, coma; dermatitis; The substance and the vapor irritates the eyes, skin and respiratory tract. Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. The substance may cause effects on the CNS.	Repeated or prolonged contact with skin may cause dermatitis.	Eyes, skin, respiratory system, CNS, liver, kidneys
Butyl Acetate (123-86-4)	1-5	1.7	PEL: TWA 150 ppm TLV: TWA 150 ppm	1700 ppm	Strong fruity odor	Irritant; Headache; Drowsiness; Narcosis; Irritates the eyes and respiratory tract. Exposures far above PEL could cause lowering of consciousness.	Defats skin	Eyes, skin, respiratory system, central nervous system

MIL-81772B – Thinner Aircraft Coating								
Methyl Ethyl Ketone (78-93-3)	30.5	1.4 (200°F)	PEL: TWA 200 ppm TLV: TWA 200 ppm	3000 ppm	Acetone-like odor	Irritant; Headache; Dizziness; Vomiting; Dermatitis; The substance irritates the eyes and respiratory tract. May cause effects on the CNS. Exposure far above the PEL may result in unconsciousness.	Defats skin; Animal tests show that this substance possibly causes toxic effects upon human reproduction.	Eyes, skin, respiratory system, central nervous system
Toluene (108-88-3)	10.5	1.1	TWA 200ppm, Ceiling 300 ppm, 10-minute maximum peak - 500 ppm REL: TWA 100ppm TLV: TWA 50 ppm (skin)	500 ppm	Benzol-like odor	Irritates the eyes and respiratory tract. Exposure could cause CNS depression. Exposure at high levels may result in cardiac dysrhythmia, unconsciousness and death.	Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the CNS resulting in decreased learning ability and psychological disorders. Animal tests show that this substance possibly causes toxic effects upon human reproduction.	Eyes, skin, respiratory system, central nervous system, liver, kidney
N-Butyl Acetate (123-86-4)	11	1.7	PEL: TWA 150 ppm TLV: TWA 200 ppm	1700 ppm	Strong fruity odor	Irritant; Headache; Drowsiness; Narcosis; Irritates the eyes and respiratory tract. Exposures far above PEL could cause lowering of consciousness.	Defats skin	Eyes, skin, respiratory system, central nervous system
Xylene (1330-20-7)	7		PEL: TWA 100 ppm TLV: TWA 100 ppm			Irritant		

This information is based on the MSDSs for CARC paints and the NIOSH Pocket Guide to Chemical Hazards, DHHS (NIOSH) Publication No. 99-115, April 1999.

1. LEL - Lower Explosive Limit
2. PEL - Permissible Exposure Limit (OSHA)
   REL - Recommended Exposure Limit (NIOSH)
   TLV - Threshold Limit Value
   TWA - Time Weighted Average
3. IDLH - Immediately Dangerous to Life or Health

TAB E – Occupational Safety and Health Guidance

The following discussion of various occupational exposure criteria provides a framework to evaluate the exposures that occurred during the Gulf War. A direct comparison of the exposures during the Gulf War to these standards is theoretical since no workplace measurements were taken during the war. These standards are discussed in detail below and in the applicable cited references, but the most important aspect of this discussion is that there were no measurements taken during the Gulf War for direct comparison.

Nevertheless, two conclusions can be drawn. First, current Army and federal occupational and safety directives clearly call for the use of personal protective equipment (PPE), including respiratory protection, during polyurethane (CARC) painting operations. Based on experience and professional judgment of the health and safety professionals monitoring the CARC painting operations in-theater, unprotected personnel who were spray painting CARC in the conditions documented in the Gulf were exposed to potentially hazardous conditions.

A. Occupational Safety and Health Requirements

Most of the standards established by occupational health authorities are based on routine time-weighted exposures over a working lifetime, typically 8 hours per day, 40 hours per week. Two exceptions are the short-term exposure limit (STEL) and the ceiling limit.

The STEL is defined as a 15-minute time-weighted average that should not be exceeded at any time during the workday. The STEL allows for brief excursions above the 8-hour time-weighted average, as long as the daily average exposure is less than the standard. In contrast, the ceiling standard is a limit that should never be exceeded at anytime during the workday.

The Occupational Safety and Health Administration (OSHA) establishes legally enforceable occupational exposure limits to substances. OSHA sets these standards in the form of permissible exposure limits (PELs). Currently, OSHA does not have a permissible exposure limit for HDI as either a monomer or a prepolymer. (Note: HDI may be present in CARC as either a monomer or a partially reacted prepolymer, also called an oligomer. This is significant because the monomer is more volatile and usually exists as a vapor after CARC has been sprayed. On the other hand, the prepolymer is less volatile and is usually present as an aerosol mist or droplet after CARC has been sprayed.)

The National Institute for Occupational Safety and Health (NIOSH) developed a recommended exposure limit (REL) for HDI monomer of 35 $\mu g/m^3$ or 0.005 parts per million (ppm), but has not established a recommended exposure limit for the HDI prepolymer.[182] The NIOSH REL is a time-weighted-average value for a normal working lifetime (up to 10 hours per day, 40 hours per week, for 40 years). NIOSH also established a ceiling value of 140 $\mu g/m^3$ (0.020 ppm) for HDI

[182] US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Pocket Guide to Chemical Hazards, June 1994, p. 160.

monomer.[183] A ceiling value is a concentration that should not be exceeded during any part of the working exposure; if instantaneous monitoring is not feasible, the ceiling must be assessed as a 10-minute time-weighted-average (TWA) exposure for HDI.[184] Though the NIOSH recommended exposure limits have undergone study, they have not completed the regulatory review process to become legally enforceable OSHA standards.

The American Conference of Governmental Industrial Hygienists (ACGIH) has also established threshold limit values (TLV®). [Note: Threshold limit values are registered trademarks of the American Conference of Governmental Industrial Hygienists.] Threshold limit values refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects. However, because of wide variation in individual susceptibility, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit value (TLV®). A smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness.[185] The TLV® for HDI monomer is 34 $\mu g/m^3$ (0.005 ppm).[186] The level of exposure above the threshold determines the severity of the adverse health effect. The American Conference of Governmental Industrial Hygienists considers threshold limit values to be recommendations to be used as guidelines for good practice.[187]

An exposure limit for the HDI prepolymer has not been established by OSHA, NIOSH or ACGIH. Oregon is the only state OSHA program that has established an exposure limit. Oregon's 8-hour time-weighted average limit for HDI prepolymer is 500 $\mu g/m^3$ with a ceiling level of 1000 $\mu g/m^3$.[188] In addition, Bayer Chemicals, a leading producer of HDI, established a corporate recommended ceiling level for HDI of 0.02 ppm.[189]

Despite the prevalence of occupational health and safety exposure limits and regulations in the military workplace during peacetime, regulations from the Occupational Health and Safety Administration (OSHA) do not apply in combat situations. Though the Department of Defense states that all DoD personnel worldwide fall under OSHA regulations, exemptions or exceptions

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[183] US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Pocket Guide to Chemical Hazards, June 1994, p. 160.

[184] US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Pocket Guide to Chemical Hazards, June 1994, p. x.

[185] 1999 TLVs ® and BEIs®: Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, Cincinnati, OH: American Conference of Governmental Industrial Hygienists, 1999, p. 3.

[186] 1999 TLVs ® and BEIs®: Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, Cincinnati, OH: American Conference of Governmental Industrial Hygienists, 1999, p. 41.

[187] 1999 TLVs ® and BEIs®: Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, Cincinnati, OH: American Conference of Governmental Industrial Hygienists, 1999, p. 4.

[188] Memorandum for All Medical Facility/SGPB from Detachment 1, HSC/OEMI, Subject: "Consultative Letter, AL-OE-BR-CL-1998-0105, 1,6-Hexamethylene Diisocyanate Exposures During Polyurethane Spay Painting Operations," August 28, 1999, p. 1-2.

[189] Bayer Corporation, Hexamethylene Diisocyante Based Polyisocyante Health and Safety Information, Pittsburgh, PA: Bayer Corporation, 1999, p. 2.

from this oversight for military personnel apply in military-unique operations and workplaces (e.g., a wartime setting).[190] However, the Department of Defense retains its obligation to protect the health of its servicemembers at all times.

B. Safety Guidance Prior to Operation Desert Shield/Storm

When troops and vehicles deployed to the Gulf for Operation Desert Shield in 1990, a detailed body of doctrine already existed for the use of CARC and the establishment of paint sites. Military technical guides, manuals, and bulletins, as well as OSHA regulations, clearly detail the necessary procedures involved in establishing CARC painting operations.

Army Technical Guide Number 144, "Guidelines for Controlling Health Hazards in Painting Operations" clearly spells out the procedures for proper set-up and testing from the initial stages of the operation. As Technical Guide No. 144 explains, "... statistically valid personal samples must be collected for HDI ... results determine the required types and level of respiratory protection and engineering controls."[191] Not only is personnel testing required for paint site set-up and annual monitoring, but also when any change occurs in an existing site's process, controls, or personnel. Such change requires additional environmental and personnel monitoring.

All types of monitoring are performed in conjunction with a standardized medical surveillance process. A pre-placement, or baseline health evaluation, is the first step in medical surveillance. Baseline determination involves three main steps: 1) determining an individual's medical and occupational history, with emphasis on prior exposure to HDI, allergies, respiratory disease, and smoking; 2) a physical examination with attention to the respiratory system; and 3) clinical laboratory tests (e.g., chest x-ray, pulmonary function tests). An annual physical examination and a pulmonary function test should follow the establishment of baseline data.[192]

The use of proper respiratory protection, particularly in spray painting operations, is vital when working with CARC. Due to the significant toxicity and lack of odor-threshold warning properties associated with HDI, OSHA dictates the use of only positive-pressure air-supplied respirators.[193,194] This guidance is echoed by the National Institute for Occupational Safety and

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[190] Department of Defense Instruction, 6055.1, "DoD Safety and Occupational Health (SOH) Program," August 19, 1998, p. 2.

[191] US Army Environmental Hygiene Agency, "Guidelines for Controlling Health Hazards in Painting Operations," Technical Guide 144, August 24, 1987, p. 2-1. Note: A personal sample is taken with a monitoring device on the person to measure the amount of an individual's exposure.

[192] US Army Environmental Hygiene Agency, "Guidelines for Controlling Health Hazards in Painting Operations," Technical Guide 144, August 24, 1987, p. 7-3.

[193] US Department of Labor, Occupational Safety and Health Administration, "OSHA Standards Interpretation and Compliance Letters," March 3, 1986. Web site http://www.osha-slc.gov/OshDoc/Interp_data/I19860303.html.(as of January 21, 1999)

[194] OSHA has subsequently revised its respiratory guideline to allow for the use of air purifying respirators in polyurethane (CARC) painting operations. OSHA Instruction CPL 2-0.120, Inspection Procedures for the Respiratory Protection Standard of September 25, 1998, established a new policy such that "where an effective change schedule is implemented, air purifying gas and vapor respirators may be used for hazardous chemicals, including those with few or no warning properties." This policy, however, was not in effect during the time period addressed in this report.

Health (NIOSH),[195] and the Department of the Army.[196] A positive-pressure air-supplied respirator is one in which the pressure inside the mask is higher than the outside environment. Clean, supplied air constantly flows into the mask from a tube for inhalation, while exhaled air exits the mask through vents. Either a full face respirator or a half-face respirator with goggles is appropriate.

Unlike spray painting operations, brush or roller painting does not cause significant aerosolization of paint constituents, and exposures to HDI are at much lower levels. In large open bays and outdoors, the potential for overexposure when using brush and rollers is remote.[197]

Workers painting or mixing CARC must use not only respiratory protection, but they must wear eye protection and clothes that provide full skin coverage and protection from contact with CARC. Gloves and coveralls are particularly important, especially gloves.[198] As noted earlier, HDI is both a skin and eye irritant.

Beyond physical personal protective equipment, training and the dissemination of information on the hazards associated with CARC application also reduce the risks of worker exposure. Material safety data sheets (MSDS), which detail hazards, protective measures, and chemical formulation, accompany all batches of paint. Federal regulation[199] requires that material safety data sheets be filed in a location readily accessible to workers exposed to a hazardous substance, such as CARC. Federal law also requires the use of material safety data sheets in training new workers.[200]

In 1988, the US Army Safety Center produced a safety support pamphlet about CARC painting that was available as a reference for civilian and military safety offices. This comprehensive guide discusses the required safety equipment and procedures for a CARC painting operation. The pamphlet also explained each of the potential components of a CARC system—the primers, solvents, and topcoats—and the dangers of each. (Primers were not used in the painting process during Operations Desert Shield/Storm.) In addition, the pamphlet included suggestions on ways that safety professionals could train personnel to work safely with CARC.[201]

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[195] Letter from the National Institute for Occupational Safety and Health (NIOSH), August 7, 1990.
[196] Headquarters, Department of the Army, Technical Manual 55-1500-345-23, "Painting and Marking of Army Aircraft," June 12, 1986, p. 8-16.
[197] US Army Environmental Hygiene Agency, "Guidelines for Controlling Health Hazards in Painting Operations," Technical Guide 144, August 24, 1987, p. 2-3.
[198] US Army Environmental Hygiene Agency, "Guidelines for Controlling Health Hazards in Painting Operations," Technical Guide 144, August 24, 1987, p. 2-5.
[199] US Department of Labor, Occupational Safety and Health Administration, Hazard Communication Standards, 29 CFR 1910.1200 (b)(3)(ii).
[200] US Army Environmental Hygiene Agency, "Guidelines for Controlling Health Hazards in Painting Operations," Technical Guide 144, August 24, 1987, p. 4-1.
[201] Industrial Safety and Installation Support, "Chemical Agent Resistant Coating, A Safety Support Pamphlet," Ft. Rucker, Alabama, January 9, 1988.

C. Material Safety Data Sheets

The military uses material safety data sheets (MSDS) to ensure that health and safety information associated with a product is available to the users. The military also uses MSDSs to ensure full disclosure of information regarding the types of raw materials used in the formulations. Material safety data sheets accompany each product. Federal regulations[202] require that all material safety data sheets be filed in a location readily accessible to workers potentially exposed to hazardous substances, such as CARC.[203] In practice, the material safety data sheets are usually taken from the package of paint cans and then filed.

D. Hazard Communication Program

Military regulations and standard operating procedures require conformance to, and compliance with, public law and national consensus standards for the hazard communication program (HAZCOM). DoD Instruction 6050.5, the Department of Defense Hazard Communication Program, outlines responsibilities and procedures for a comprehensive hazard communication program that includes training for DoD personnel in potential occupational health hazards. Department of Defense personnel are to be informed of safe work practices and are to be trained in the selection, use, and availability of personal protective equipment (PPE) to prevent injuries and illnesses. It states that it is the Department of Defense policy to protect personnel from the adverse effects of workplace hazardous materials and waste, to reduce chemically related injuries and illnesses, and to establish and maintain a standardized hazardous materials information system. Each service and component is required to establish and maintain hazard communication programs that conform to the requirements of DoD Instruction 6050.5 and comply with the Occupational Safety and Health Administration (OSHA) hazard communication requirements.[204]

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[202] US Department of Labor, Occupational Safety and Health Administration, Hazard Communication Standards, 29 CFR 1910.1200.

[203] US Army Environmental Hygiene Agency, "Guidelines for Controlling Health Hazards in Painting Operations," Technical Guide 144, August 24, 1987, p. 4-1.

[204] Department of Defense, Instruction 6050.5, "DoD Hazard Communication Program," May 6, 1996, p. 1-6.

TAB F – Changes in this Report

Following publication of the interim Chemical Agent Resistant Coating (CARC) Environmental Exposure Report (EER) on February 22, 2000, comments were received from various veterans and from the Presidential Special Oversight Board (PSOB). This updated report has been written to include information based on additional research, interviews with veterans, consultation with subject matter experts, and new information that we have obtained since publication of the interim CARC EER. This report follows the same format as our interim report with limited editing to improve readability.

Based on new information from veterans since publication of the interim report, the discussion of the civilian painters from Anniston, Alabama was modified to reflect that several of the painters have reported medical problems which they have associated with their exposure to CARC during the Gulf War. Their comments and concerns were forwarded to the Army's Office of the Surgeon General who has agreed to arrange for further medical follow-up through the occupational medicine clinic at Anniston Army Depot. In addition, a paragraph was added to address the PSOB's request that we describe the efforts OSAGWI has taken to implement lessons learned and to enumerate the agencies with which OSAGWI has coordinated.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # In Sec V	OSAGWI Remarks
				344		<=TOTALS=>	46	202	30		27	33	6		

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174			?	1	Hafar [aka Hafir] Al Batin	Destroyed by Patriot			1	#155				26	Same ref as #173 for Feb 25th Z - likely dupe of firing against KKMC on 24th. No other sources report firing on this target on Feb 25.
175	26 Feb	0126-9	C	1	Doha/Qatar	Impact 40 nm N of Doha		1		#169				11	Note 26/0126C = 25/2226Z. Cites are further reporting on activity first noted in #169.
176	26 Feb	0130	C	1	Dhahran/ Qatar	Scud fell into Persian Gulf		1		#169				11	Ref notes about 1:30 a.m. on Feb 26 one Scud was fired toward Dhahran or possibly Qatar. Note ~1:30 AM (C) on 26th = 2226Z on Feb 25. Clear dupe of last Scud firing.
177	26 Feb	0600	?	1	Damman	Al Kobar [aka Khobar] Village (40 MIA)		1		#165				10	Refs note hit on Khobar warehouse and high casualties - clear late reporting/update on barracks disaster.
178	26 Feb	1558	C ?	2	Dhahran	(none)							2	None	Hand log noted two launches at about 1558 on Feb 26 (with azimuths threatening Israel and E. KTO). However, additional ref notes continuing analysis of data on 26/1557 activity indicates an explosion was involved rather than a launch. No other refs to this activity. Non-launch event.
179	26 Feb	2032	C	1	Dhahran	Billeting/AUJAN/475th POL		1		#165				10	Further update reporting on barracks hit and casualties make this clear dupe of #165.

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170	25 Feb	2200	Z	1	Bahrain	(none)			1	#165, #169				10, 11	In addition to same cite used to create #169, CURR refs for this entry include ops log noting three launches earlier at 1738-1742Z. Latter ref relates to #165 firing resulting in high casualties in a barracks. Bulk of evidence for #165 indicates only one Scud that may have broken up with part landing in the Persian Gulf. Probable dupe of two previous entries.
171	25 Feb	2200	Z		Doha	(none)		1		#169				11	Same CURR single "late entry" ref as for #169.
172	25 Feb	2226	Z	1	N. Saudi	(none)		1		#169				11	Ref for this entry notes Iraqi launch threatening northern KTO. Date/time confirm dupe of #169.
173	25/6 Feb	0400	Z		Riyadh	Destroyed by Patriot			1	#159				22	CURR time entry is date-time group of msg reporting on earlier activity (reporting period for Feb 25th Z). However, activity suggests reporting on Feb 24 attack on Riyadh (#159). The cited summary of activity did not note late 25th devastating hit on barracks. No other sources report firing on this target on Feb 25.

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166	25 Feb	1736/ 2058	Z/ C	1	Dhahran	Impacted United States barracks/burns/475 QM/GP: to 85th Evac Hospital		1		#165				10	Because of casualties, large number of refs to this activity continued for days as casualty figures were revised upward. Time and description mean dupe of #165.
167	25 Feb	1816	Z	1	Dhahran	Impact		1		#165				10	Further entry on #165 activity.
168	25 Feb	2034	C	1	Bahrain	Fell into ocean between sites		1		#165				10	Single ref for this entry noted impact in Gulf but also for same incident noted hit on barracks.
169	25 Feb	2200	Z	1	King Fahd	(none)	1							11	Single ref has "late entry" for 2200Z noting a launch, missile break-up, and multiple impacts including King Fahd Airport, Bahrain, and Persian Gulf off Qatar. Ref noted Saudis said missile landed in the Gulf at Doha (Qatar). Actual launch time was later than "late entry" - 2226Z on 25th (26/0126C) Valid initial cite for last confirmed Scud firing of Gulf War.

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160	24 Feb	1823	Z	1	Riyadh	Scud destroyed		1		#159				22	Correct time for this activity.
161	24 Feb	2124	C	1	Riyadh	Damage to school		1		#159				22	Clear dupe of #159 with correct (C) time.
162	24 Feb	2125	C	1	Riyadh IAP	Warhead kill by Patriot		1		#159				22	A second impact may have been debris. Time/location mean dupe.
163	24 Feb	2126	C	1	KKMC	Engaged by Patriot/break up		1		#159				22	Refs cited for entry support Riyadh as target. One source noted projected impact just N of Riyadh but indicated KKMC at risk. Another source indicated one Scud engaged and another broke up in flight, but evidence supports one Scud.
164	24 Feb	2130	C	2	Riyadh	Engaged by Patriot		1		#159		1		22	Ref noted three Scuds for day (24th) with two at Riyadh (correct). Only second of these associated with this activity, hence one wrong salvo size.
165	25 Feb	1732	Z	1	Dhahran	(none)	1							10	Valid initial ref for one Scud not engaged by Patriots that caused more United States casualties than any other engagement in Gulf War when it hit warehouse/ barracks.

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152	24 Feb	0435-8	C	1	Riyadh	Killed by Patriot/10km NW/W (?)		1		#150				21	Time and location indicates further info on #150 activity.
153	24 Feb	0436	C	1	Riyadh	Destroyed by Patriot		1		#150				21	Time and location indicates further info on #150 activity.
154	24 Feb	0440	C	2	Riyadh/ Dhahran	No BDA		1		#150			1	21 and None	Time and target point to one dupe of #150. There is no corroboration for Scud at Dhahran at this time.
155	24 Feb	0917	Z	1	King Khalid AF	Fell SE of KKAF	1							26	Valid initial entry.
156	24 Feb	0917-8	Z	1	KKMC	Warhead kill/debris 10 nm E		1		#155				26	Time/area clearly indicates dupe of #155. Notes one Patriot killed Scud.
157	24 Feb	1218	C	3	KKMC	1 overflight/1 engaged/1??		1		#155		2		26	Cannot corroborate more than one Scud at this time. One ref recorded three Scuds for day (correct). One ref noted second Scud disappeared from radar (possibly debris). Assess two as inaccurate salvo size.
158	24 Feb	1225	C	2	KKMC	Report: Scud kill/no damage		1		#155		1		26	Cannot confirm more than one Scud at this time. One is dupe of #155 based on time/area.
159	24 Feb	1725	?	1	Riyadh	Mission kill	1							22	Time should be 1825Z vice 1725 as subsequent dupe entries make clear. Ref noted "approx 24/1725Z." Possible originator error in translating from local (C) time. No evidence of launch at 1725Z (or C). Valid first entry.

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144	22/3 Feb		?	3	KKMC	2 intercepted/1 exploded in flt		2		#125		1		24	Date-time group of ref was very early on 23rd but covered activity "in past 24 hours." Some refs noted three vs. two Scuds fired but bulk of evidence indicated two. Another dupe of #125 based on target and date.
145	22/3 Feb		?	2	Bahrain	1 intercepted/1 landed in Gulf		2		#136				8	Target and description clearly indicate dupe of #136 activity.
146	23 Feb	0159	Z	1+ (1)	Dhahran	No impacts detected	2							9	Ref noted one, possibly two, fired. Evidence favors two. First entry on corroborated event.
147	23 Feb	0459	C	2	Dhahran (toward)	Landed SW of Dhahran/ desert		2		#146				9	Target and time indicate dupe of #146. Taken together, evidence suggests one impact SW and one impact NW of Dhahran.
148	23 Feb	0503	C	1	Riyadh/ KKMC	(none)		1		#146				9	One ref notes at risk areas included Riyadh, KKMC, and Dhahran but that impact location was in Dhahran area. This and time point to dupe of #146.
149	23 Feb	0507	C	1	King Fadh	Impact 10 nm NE		1		#146				9	Time and location (Dhahran area) point to clear dupe of #146.
150	24 Feb	0132	Z	1	Riyadh	Damage to unocc. school @ 500m from Riyadh Sheraton	1							21	First valid ref to intercepted Scud that still caused damage.
151	24 Feb	0432	C	1	Riyadh	Intercepted by Patriots		1		#150				21	Time and location indicates further info on #150 activity.

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136	21 Feb	2331	Z	3	Bahrain/ Dhahran	1 engaged over water/1 outside of Patriot range/1 broke up/no impact	3							8	Numerous refs to this activity with two Scuds hitting in Persian Gulf and one engaged with possible debris falling on Bahrain. First entry.
137	21 Feb	2331	Z	1	SA (undeter-mined)	No damage/injuries		1		#136				8	Time indicates further info on #136 activity.
138	21 Feb	2332	Z	1	Bahrain	Engaged by Patriot		1		#136				8	Time indicates further info on #136 activity.
139	21 Feb	2334	Z	1	Dhahran	No known damage		1		#136				8	Time indicates further info on #136 activity.
140	22 Feb	0233	C	3	Bahrain/ Dhahran	1 engaged/2 in gulf/debris @ Bahrain		3		#136				8	Note 22/0233C = 21/2333Z. Time indicates dupe of #136.
141	22 Feb	0234	C	2	Doha	1 engaged/1 overflew		2		#136				8	Note Doha is in southern Qatar. Scud engaged by Patriot battery in Bahrain. Time indicates further reflections of #136 events.
142	22 Feb	0245	C	1	Riyadh	(none)		1		#136				8	Two refs noted initially projected target of Riyadh or KKMC but actual impact E. of Dhahran. This and times indicate dupe of #136.
143	22 Feb	1406	Z	2	KKMC	1 engaged/1 malfunctioned		2		#125				24	"Period covered" in msg points to activity on 22nd but time, target, and description clearly point to event on 21st and hence dupe of #125. No other indications of Scud activity on 22nd.

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128	21 Feb	1707	C	2	KKMC/ Al Jubayl	Kill on 2 TBMs (1 exploded in flt)		2		#125				24	One ref noted two at KKMC and "no info on third - heading towards Al Jubayl." Bulk of info indicates two Scuds fired at KKMC and this is dupe of activity in #125 and subsequent.
129	21 Feb	1710	C	3	KKMC	2 intercepted/target 10mi NW		2		#125		1		24	Some sources indicate three vice two Scuds launched. Weight of evidence indicates two. Time indicates dupe of #125 and subsequent.
130	21 Feb	1800	Z	1	E of KKMC	Broke up/impact 50 km E	1							25	Was third missile of day at KKMC area. First entry on this corroborated attack.
131	21 Feb	1801	Z	1	KKMC	Impact 30 km SW of KKMC		1		#130				25	Different impact location from #130 probably was predicted vs. actual after breakup. Time points to dupe of #130.
132	21 Feb	1800	Z	1	Saudi (NFI)	U/I target/no sig. Damage		1		#130				25	Time establishes dupe of #130.
133	21 Feb	2102	C	1	Riyadh (toward)	Exploded early in flight		1		#130				25	Actual target probably KKMC vs. Riyadh.
134	21 Feb	2103	C	1	KKMC	Out of footprint		1		#130				25	Further info on #130 activity.
135	21 Feb	2111	C	2	KKMC	Patriots fired		1		#130		1		25	Bulk of evidence indicates only one missile and no Patriot engagement. Time points to dupe of #130.

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121	16 Feb	0200	C	1	Dharahn	Fell into Persian Gulf		1		#120				7	Target area wrong but time (C vs. Z) indicates dupe of #120. Single open source ref noted Scud toward Dhahran (~40 nm further S). Clearly same activity.
122	16 Feb	0202	C	1	Al Jubayl (SA)	Landed in water		1		#120				7	Time/locations indicate further info on #120 activity.
123	18 Feb	0215	Z	3	Dharahn	(none)			3	#2, #5				None	Month unclear in single ref. Time appears to point toward Jan vice Feb (false target engagements) in #2 and #5.
124	18 Feb	0215	Z	1	Al Khobar	Debris/damage E side of base			1	#2				None	Same single ref as for #123.
125	21 Feb	1000	Z	2	KKMC	(none)	2							24	Time almost certainly later than ref's "as of" time of 1000Z used for entry. No other evidence of activity at noted time. Assess as first entry on activity described in subsequent entries.
126	21 Feb	1406	Z	2	NE of KKMC	Intercepted by Patriots		2		#125				24	Better/more data on #125 activity based on date, target, and bulk of evidence.
127	21 Feb	1652	C?			(none)							1	None	Single entry reported air and Scud "activity" in Iraq but not launches. No other evidence of Scud launch until ~15 minutes later (assuming time = C). Assessed as not Scud firing (no-match event).

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115	14 Feb	1148	C	1	Riyadh	***** (?)			1	#111				23	Times equate to fire at Hafir al Batin. Initial general direction would have been toward Riyadh. Assess as wrong target but dupe of #111.
116	14 Feb	1230	C ?	1	Hafar [aka Hafir] Al Batin	Fragment struck bldg/3 injuries		1		#111					Time was when spot report on debris received vice attack time. Clearly further info on #111 activity.
117	14 Feb	1915	C ?	3	Hafar [aka Hafir Al Batin] (KKMC)	Impact VII Corps sector/large pieces of debris fell in 5 areas/MOPP 4/no chem or injuries/150 meters from shower point		3		#111, #113				23	Cannot find entered time in either ref, both were after-the-fact summaries. No Scud activity at noted time. Description points to clear dupe of #111 and #113 for three missiles.
118	14 Feb	2045	C ?	1	KKMC	Civilian/KIA: warehse destroyed		1		#111				23	Time is late but single ref was labeled "Scud Launch Update." Description clearly indicates dupe of #111.
119	15 Feb	0834	Z	1	Hafir Al Batin	Minimal effect on friendly ops		1		#111				23	Refs are summaries with date-time groups on 15th. Noted this activity was first daylight Scud attack and first directed at Hafir al Batin, therefore clear dupes.
120	15 Feb	2301	Z	1	Al Jubayl	Impact 10NM SW/no damage	1							7	Four refs for this initial entry on this activity.

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110	12 Feb		?	1+(1?)	Riyadh	(none)		1		#104				20	Single ref noted three launches "last night" (11th) - two at Israel and one at Riyadh. Disregarded "+(1?)." Clear dupe of #104.
111	13 Feb (wrong date)	0842	Z	2	Hafar [aka Hafir] Al Batin (KKMC)	Broke apart/5 impacts @ Hafar	2							23	All refs cited by CURR for this entry had activity on Feb 14 vs. Feb 13 as entered. Note same time as #112. Assess date should have been 14th vice 13th. As such, first entry for this activity. Several refs noted Scuds broke up in air and landed at (up to five) different locations. At least two and probably five Scuds involved. Note Hafir Al Batin is ~43 mi NE of KKMC and not same location.
112	14 Feb	0842	Z	2	Tri-border	Impact S of Tri-Border damage to bldg/no injuries		2		#111				23	Hafir al Batin is ~50 nm from Tri-Border area (Saudi Arabia/Kuwait/Iraq). Time indicates dupe of #111 with correct date.
113	14 Feb	1140	C	3	Hafar Al Batan (aka Hafir Al Batin)	2 hit by Patriots/1 hit in desert	3			#111				23	Initial indication of three additional Scuds in this salvo - assessed valid. Patriots did not engage, however.
114	14 Feb	1142	C	2	KKMC	Outside of Patriot range/fell in civilian district/minor damage		2		#111				23	Note some refs considered Hafir al Batin equated to KKMC. Patriots at KKMC were out of range for Hafir al Batin. Dupe of #111.

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104	11 Feb	1920	Z	1	Damman	(none)	1							20	Ref notes "probably toward Damman." No other evidence of launch at Damman/Dhahran area at this time. However time equates to Scud at Riyadh. As such - first entry for this incident.
105	11 Feb	1920	Z	1	Riyadh	Diverted/impact University pool		1		#104				20	Dupe of #104 but with correct target (note times).
106	11 Feb	2220-2	C	1	Riyadh	Engaged/warhead exploded beside school/extensive damage		1		#104				20	C time equates to #104 Z time indicating dupe of #104 but with correct target.
107	11 Feb	2225	C	1	Riyadh	Impact 30nm SW		1		#104				20	Time indicates another dupe of #104 with correct target.
108	11 Feb		?	3	Saudi (NFI)	(none)		1		#104		2		20	Of two refs for this entry - one notes two at Israel and one at KTO and other notes one at Israel and three at KTO. Most sources indicate one vice three missiles at KTO this period (at Riyadh). Dupe of #104.
109	12 Feb	1920	Z	1	Riyadh (toward)	Patriot engaged/minor damage			1	#104				20	One of refs for this entry had correct time but on Feb 12th vs.11th. No other evidence for any Scud firings on 12th. Suspect dupe of #104.

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97	3 Feb	0120	C	2	Riyadh	Impacts 30 nm S and 55 nm N		1		#93		1		18	One of two refs claimed two Scuds at Riyadh but most sources report only one Scud at this time. Other considered wrong salvo size.
98	3 Feb	0233	?	1	Riyadh	(none)			1	#93				18	CURR unable to identify ref citing entered time. No other substantiation. Presumed late reporting on #93 activity.
99	7 Feb	2255	Z	1	Riyadh	Intercepted by Patriot	1							19	Numerous sources reported this Scud intercepted by two Patriots but resulting in ground explosion. Initial entry for this corroborated attack.
100	7-8 Feb		?	1	Riyadh	Destroyed		1		#99				19	CURR annotated only one Scud - some refs for this entry note two. Weight of evidence = one.
101	8 Feb	0155-6	C	1	Riyadh	Patriot destroyed/debris prk lot		1		#99				19	Separate debris impacts may have initially suggested separate Scuds. Time confirms dupe of #99.
102	8 Feb	0220	?		O/A (?)	(none)			1	#99				19	Probable late ref to #99 but too little detail to be completely certain. Ref had time of O/A (on or about) 0220.
103	8-9 Feb	0400	Z	1	Riyadh	Intercepted/uninhabited area		1		#99				19	Time (0400Z) was DTG of summary msg not incident. Description strongly indicates dupe of #99.

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91	29 Jan	Even-ing	?	2		(none)			1	#87		1		17	One ref for this entry appeared to summarize previous day's activity (one Scud at Riyadh and one at Israel on 28th). Other source included same info in entry for 29th. There are no other indications of any Scud firings on 29th, therefore assessed as previous day's activity. Neither ref noted two Scuds fired at KTO so second missile is incorrect salvo size in CURR entry.
92	29 Jan	0004	C	1	Riyadh	Engaged by Patriot			1	#87				17	Single ref was summary slide showing attack at time noted. No other corroboration for this time. Suspect dupe of #87 with time about 2 hours late.
93	2 Feb	2141-2	Z	2	Riyadh	Destroyed/minor damage and casualties	1					1		18	Most sources indicate one Scud - second unsubstantiated. Initial entry for this Riyadh activity.
94	3 Feb	Early AM	C	1	Riyadh	Intercepted/warhead fell 1/4 m[i?] PX		1		#93				18	Target and general time strongly indicated further info on #93 activity.
95	3 Feb	0042	C	1	Riyadh	Destroyed by Patriot		1		#93				18	Time (C vs. Z) clearly points to dupe of #93.
96	3 Feb	0100	C	1	Riyadh	Engaged/warhead exploded in suburb/damage to several bldgs		1		#93				18	Description and time confirms dupe of #93.

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87	28 Jan	1755	Z	1	Riyadh	Intercepted by Patriot	1							17	Several sources reported a Scud kill at Riyadh (a few refs suggested two to three Scuds but rest of refs note only one with another fired later toward Israel). Initial corroborated reflection of this attack.
88	28 Jan	1758	Z	1	Riyadh	Destroyed by Patriot		1		#87				17	Time clearly indicates this is further reflection of Riyadh activity in #87.
89	28 Jan	1904	Z	2-3	Riyadh	NFI			1	#87		2		17	One log ref had entry for 2104C (1804Z) with three Scuds reported against Riyadh. Other ref (summary message) included 1904Z time which does not correlate with either C or Z time for corroborated incident. Suspect one-hour error in this summary. Also, bulk of evidence supports only one Scud firing just before 2100C, hence two uncorrelated salvo size.
90	28 Jan	2057	C	1	Riyadh/Al Jabal	Destroyed, debris fell on farm		1		#87				17	Several sources noted debris in rural area S of town. C time correlates with #87 Z time. Clear dupe.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # In Sec V	OSAGWI Remarks
82	26 Jan	2310	C	1	Dhahran	Engaged by Patriot							1	None	Two almost identical Scud/Patriot Results tables vary only in attributing this launch against Dhahran vs. Riyadh. Weight of evidence clearly favors Riyadh with this entry (like #81) unmatched.
83	26 Jan	2332	C	1	Riyadh	Impact 1/4 mi SW of MODA bldg		1		#75				16	Time indicates further reflection of Riyadh activity in #75.
84	26/7 Jan	0300	Z	1	Riyadh	Intercepted by Patriot		1		#75				16	Time entry is date-time group of SITREP summary msg, not incident time. Clearly summarizing #75 Riyadh activity.
85	27 Jan	48 hrs	?	4	Saudi (NFI)	All engaged by Patriot			4	#62, #69, #75				15, 6, and 16	Source was 48-hour wrap-up. Four does not include unsubstantiated launch against Dhahran.
86	28 Jan	0710	Prob C	1	Dhahran	1 HTH contractor hit by debris			1	Unk				Unk	Source was NBC log from E of KKMC bemoaning unavailability of commercial CWA decontamination chemical (HTH = calcium hypochlorite) because supplier/contractor took Scud damage. Probably reflection of unidentified previous attack vice new separate incident. No other evidence of activity at noted time/location.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # in Sec V	OSAGWI Remarks
77	26 Jan	2018	Z	1+(1)	Saudi	Possible warhead kill		1		#75		1		16	One confirmed, one unconfirmed initially reported fired at KTO. Later, better assessments support only one. Ref gave start/end times for all attacks including against Israel. CURR time is end time and involved attack on Israel. Therefore, clear dupe of #75.
78	26 Jan	2138	Z		Riyadh	Scud debris falling		1		#75				16	Assumed one missile in absence of entry. Entered time was log entry for Explosive Ordnance Disposal incident report on Scud debris, not time of attack. Clearly late reflection of #75 activity.
79	26 Jan	2248	C	1	Riyadh	Intercepted by Patriot		1		#75				16	Shift to C time. Clear dupe of #75 based on time.
80	26 Jan	2250-2320	C	1	Riyadh	Destroyed over empty field		1		#75				16	Times indicate further reflection of Riyadh activity in #75.
81	26 Jan	2300	C?		King Fadh/ KKMC	(none)							1	None	Single hand log ref noted four launches -- one at Riyadh, one at King Fadh (proper sp Fahd -- airport near Dhahran) and two at Israel. No mention of KKMC. CURR probably mislocated King Fahd Airport. However, there is no corroboration for attack on Dhahran (or KKMC) at this time -- attack was on Riyadh. Therefore, this entry is unmatched.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # in Sec V	OSAGWI Remarks
73	26 Jan	0330	C	2	Dhahran/ KFIA	Both intercepted by Patriots/1 warhead landed in Dhahran/no deaths or injuries reported		1		#69		1		6	C time for attack in #69. Best sources indicate only one Scud but three other refs reported two.
74	26 Jan	0435	C	2	Dhahran	Engaged by Patriot			1	#69		1		6	Scud activity slide included entry for 0435C (two missiles). No other source reported this time which was ~one hour late. One is likely late dupe of #69 - other wrong salvo size.
75	26 Jan	1946	Z	1	Riyadh	Detonated	1							16	Several sources reported on this single launch at Riyadh with a Patriot intercept. First entry on this corroborated attack.
76	26 Jan	1948	Z	(5)	Saudi	SA(Riyadh/2) NFI		1		#75		4		16	Two refs for this entry summarized Scud attacks. One did not note target areas for five Scuds, other indicated two toward Riyadh and rest at Israel. Best available information corroborates one Scud at Riyadh and four at Israel. Riyadh attack clearly dupe of #75, rest wrong salvo size for KTO.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # in Sec V	OSAGWI Remarks
68	25 Jan	2250	C	1	KKMC	Killed by Patriot			1	#62				15	Log entry noted one Scud inbound and also noted maintenance status at KKMC - location probably not related to Scud target. Similarity of time suggests dupe of #62 activity.
69	25 Jan	Even-ing	?	2/1	Riyadh/ Dhahran	All intercepted by Patriots	1	2		#62				15 and 6	Both of CURR's sources for this entry were 24-hour summaries without times. Riyadh attack duplicates that assessed in #62. Attack on Dhahran was said to be "last night" and actually occurred early on 26th. This is initial entry covering corroborated Dhahran attack and assessed as duplicative for two at Riyadh.
70	25/ 26 Jan		?	1	Dhahran	Intercepted		1		#69				6	Single ref marked as basis for this entry reports this attack at 0330 on 26th. Further reflection of Dhahran activity first noted in #69.
71	25/ 26 Jan		?	2	Riyadh	Intercepted		2		#62				15	Single ref was briefing slide from 26th reporting Riyadh/Dhahran attacks "last night." Clearly further reflection of Riyadh activity in #62.
72	26 Jan	0028	Z	1	Dhahran	Impact 0035		1		#69				6	Corroborated time for Dhahran attack in #69.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # in Sec V	OSAGWI Remarks
62	25 Jan	1125	Wrong C	5	Riyadh	(none)	2					3		15	Single hand log source had start (from) time of 25/2000[C] ruling out 25/1125C as correct time. Presume real time was 11:25 p.m. or 2325C. This is hour late for confirmed activity. No other support for either 1125C or 2325C incidents on 25th. Weight of evidence indicates two Scuds fired at ~2222C. Assess this entry as first for these two Scuds and excess salvo size for other three.
63	25 Jan	1921-2	Z	3	Riyadh	(none)		2		#62		1		15	Most refs for this entry also note two Scuds. Z time is approximately correct. Duplicative of #62 activity.
64	25 Jan	2223	C	1	MODA Riyadh	Patriots destroyed/Scud @ 2K S		1		#62				15	Time (C) indicates duplicative entry on #62 activity.
65	25 Jan	2224	C	2	Riyadh	Both shot down by Patriots/1 hit Dept Interior Bldg/slight injuries		2		#62				15	Duplicative and additional info on #62 activity based on time.
66	25 Jan	2233	C	1	Riyadh	Engaged by Patriot		1		#62				15	Duplicative of #62 activity based on time.
67	25 Jan	2230	C	2	Riyadh	1 destroyed/1 impact 2 km S of MODA building		2		#62				15	Duplicative (based on time) and additional info on #62 activity.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time:= Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # In Sec V	OSAGWI Remarks
54	23 Jan	1954	Z	2	Dhahran	Engaged by Patriot		2		#53				5	Further info on #53 activity. This is valid time for these incidents.
55	23 Jan	1954	Z	2	Riyadh	Engaged by Patriot		2		#53				5	Further info on #53 activity. Time indicates duplicative entry.
56	23 Jan	1957	Z	5	Saudi (NFI)	2 destroyed @ Riyadh/0 @ KKMC		4		#53		1		5	Four are duplicative. Fifth Scud at this approximate time was fired at Israel (here wrong salvo size).
57	23 Jan	2254	C	3	Dhahran	2 destroyed/1 into Gulf		2		#53		1		5	Three Scuds appear to be one too many against Dhahran based on weight of evidence. Time indicates other 2 are duplicative.
58	23 Jan	2254	C	2	Riyadh	1 destroyed		2		#53				5	Further info on #53 activity. Time indicates duplicative entry.
59	23 Jan	2258-2303	C	2/2	Dhahran/ Riyadh	All destroyed by Patriots		4		#53				5	Further info on #53 activity. Times indicate duplicative entry.
60	23 Jan	2300	C	2	KKMC	Destroyed by Patriot					2			None	A few refs note one or two Scuds engaged from KKMC but other sources indicate scepticism. This was final noted incidence of Patriot fire on false targets. See main body, Section VI.
61	24 Jan		?	4	Damman/ Riyadh	All destroyed by Patriots		4		#53				5	No time entered. One ref noted activity happened "yesterday" (Jan 23). Clear that this was later summary of activity and duplicative entry on #53 incident.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of #	False Target	Wrong Salvo Size	No Match	Event # In Sec V	OSAGWI Remarks
41	22 Jan	0143	Z	2	Riyadh	Probable kills			2	#39				13	CURR time clearly wrong - refs they cited for this incident note times around 0043Z or 0343C. No sources indicate activity at CURR noted time (0143). Likely duplicative entry based on minutes after hour.
42	22 Jan	0340	C	3	Riyadh	3 destroyed		3		#39				13	Further info on #39. Time indicates duplicative entry.
43	22 Jan	0340	C	3	Riyadh	Impact/no damage		3		#39				13	Further info on #39. Time indicates duplicative entry.
44	22 Jan	0410	Z	3	Dhahran	2 detonated 50 mi W (desert)/1 in Gulf	3							4	A few sources indicated four firings but consensus is three. First ref to this corroborated activity.
45	22 Jan	0410	Z	1	King Fahd IAP	Destroyed over KFIAP		1		#44				4	Further info on #44 activity. King Fahd IAP is near Dhahran. Time confirms duplicative entry.
46	22 Jan	0410	Z	2	Qatar	Landed north in water		2		#44				4	Further info on #44 activity. Dhahran is NW of Qatar. Time confirms duplicative entry.
47	22 Jan	0411	Z	3	E. Saudi	Not engaged		3		#44				4	Further info on #44 activity. Time confirms duplicative entry.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis							
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # in Sec V	OSAGWI Remarks
33	21 Jan	0100	C	17	Riyadh	14 shot down/3 missing		8		#14	9			1 and None	Large number not supported by other evidence. USARCENT indicated 14 kills because some Patriots went after Patriots.
34	21 Jan	0128	C	6	Riyadh	150ft SW of King Abdul Aziz/vacant lot/damage to sur[rounding] bldgs.		6		#14				13	Further info on #14. Times indicate duplicative entry.
35	21 Jan	1918	Z	1	Al Jubayl	Into N. Arabian Gulf	1							3	Several refs to this activity, some noting two Scuds. Weight of evidence supports one.
36	21 Jan	1920	Z	1	Dhahran	Landed in Gulf		1		#35				3	Further info on #35. Times, water impact confirm duplicative entry.
37	21 Jan	2220-7	C	2	Dhahran	Short of Dhahran/fell in water		1		#35		1		3	Second Scud unsubstantiated. Times and water impact indicate duplicative entry.
38	21 Jan	2225	C	2	Jubayl	Impact in water		1		#35		1		3	Second Scud unsubstantiated. Times and water impact indicate duplicative entry.
39	22 Jan	0041	Z	3	Riyadh	2 kills.1 impact north	3							13	Refs for this activity note two or three Scuds - weight of evidence supports three. Initial entry for this corroborated incident.
40	22 Jan	0047	Z	2	Riyadh	Engaged, debris shower		2		#39				13	Further info on #39. Time indicates duplicative entry.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # In Sec V	OSAGWI Remarks
22	20 Jan	2200	Z		Riyadh	Destroyed		1		#14				1	Unk nbr of Scuds -- assumed one. Times confirm duplicative entry.
23	20 Jan	2200-5	Z	4	Dhahran	All destroyed by Patriots		4		#14				1	Further info on #14. Times confirm duplicative entry.
24	20 Jan	2205	Z	2	King Fahd	Possible impact at King Fahd		2		#14				1	Further info on #14. King Fahd International Airport is near Dhahran. Times confirm duplicative entry.
25	20 Jan	2220	Z	2	Dhahran	Impact vic Dhah+G65ran IAP		2		#14				1	Further info on #14. Times confirm duplicative entry.
26	20 Jan	2330	Z	2	King Fahd	Impact outside city (CIA)		2		#14				1	Further info on #14. Times confirm duplicative entry.
27	21 Jan	0030	C	2	Al Kabor			2		#14				1	"Wrap-up" - Al Kabor is in Dhahran area. Cited sources reported in KTO local (C) time (C=Z+3).
28	21 Jan	0045	C	2	Dhahran	Destroyed		2		#14				1	Further info on #14. Times confirm duplicative entry.
29	21 Jan	0045	C	1	Dhahran	Impact in water		1		#14				1	Further info on #14. Times confirm duplicative entry.
30	21 Jan	0045	C	4	Riyadh	Destroyed/12 minor injuries		4		#14				1	Further info on #14. Times confirm duplicative entry.
31	21 Jan	0050	C	1	Riyadh	Impact		1		#14				1	Further info on #14. Times confirm duplicative entry.
32	21 Jan	0057	C	2	Al Jubayl	Destroyed		2		#14				1	Further info on #14. Times confirm duplicative entry.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # In Sec V	OSAGWI Remarks
14	20 Jan	?	?	8+	Saudi (NFI)	Engaged/destroyed	8					1		1	Numerous sources echoed this initial corroborated activity aimed at Dhahran (two at about 1845Z and two at about 2145Z) and Riyadh (four at about 2145Z). "8+" interpreted as nine -- other sources suggest as few as 6 (2 Dhahran, 4 Riyadh). Best information indicates 4 at Dhahran, 4 at Riyadh, and 1 uncorrelated if total was 9.
15	20 Jan	?	?	1	Riyadh	Impact by Riyadh/minor dam		1		#14				1	Single ref also was cited for #14. Confirmed duplication.
16	20 Jan	1843-50	Z	2	Dhahran	Destroyed		2		#14				1	One ref notes firing against Dhahran about 1850Z and at Riyadh about 2200Z. Times confirm duplicative entry.
17	20 Jan	2139	Z	2	Dhahran	1 destroyed, 1 in water		2		#14				1	Further info on #14. Times confirm duplicative entry.
18	20 Jan	2142-9	Z	4	Riyadh	Impact		4		#14				1	Further info on #14. Times confirm duplicative entry.
19	20 Jan	2150	Z	3	Dhahran	Debris fell/202 MI Bn billets		3		#14				1	Further info on #14. Times confirm duplicative entry.
20	20 Jan	2154-6	Z	2+2	Dhahran	1 Scud killed by Patriot		3		#14		1		1	CURR ref's noted three vs. four (2+2) launches. Times confirm duplicative entry.
21	20 Jan	2200-2305	Z	3	Dhahran	Destroyed		3		#14				1	Further info on #14. Times confirm duplicative entry.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # in Sec V	OSAGWI Remarks
48	22 Jan	0422	C	5	Riyadh	3 destroyed/2 SE of envelope [defended area]			3	#39		2		13	Probable late reporting of #39 activity. CURR entry was based on single ref with five vs. three Scuds. No other indications of activity at time this hand message prepared. Estimate three are duplicative and two overestimate of missiles fired.
49	22 Jan	0425	Z	1	Dhahran	1 destroyed		1		#44				4	Further info on #44 activity. Time indicates duplicative entry.
50	22 Jan	0425	C	2	Dhahran	Impact outside envelope/desert		2		#44				4	Further info on #44 activity. Time indicates duplicative entry.
51	22 Jan	1745	?	1	KKMC	Confirmed warhead kills					1			None	1 source noted this attack had no warning and another source noted possible software glitch. Evidence suggests Patriots fired at false targets.
52	22 Jan	1800	C	#	Dhahran	4 Patriot intercepts/2 detonated		1		#53	1				No nbr entered. Only one Source said two Scuds. Scored one as dupe and one as additional false target.
53	23 Jan	1945	Z	4	Damman/ Riyadh	All destroyed by Patriots	4							5	First entry for this valid activity. Best estimate is five at KTO - incl three at Riyadh and two at Dhahran. Noted time is ~nine mins early. Single source for this entry was briefing slide that may have rounded off time. No other refs substantiated this early time.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # In Sec V	OSAGWI Remarks
6	18 Jan	0315	?		KKMC				1	#2				None	Ref indicates Scuds on way to KKIA - most to Israel but one may have hit W. KTO. Duplicative false target reflection.
7	18 Jan	0400-20	C	1	Dhahran	First Scud /intercepted		1		#2				None	Ref notes first successful Scud intercept reported but later known as false target engagement.
8	18 Jan	0420	C	1	King Fadh IAP	Destroyed by Patriot		1		#2				None	Duplicative false target reflection based on time.
9	18 Jan	0450	C	1	Dhahran	Destroyed by Patriot		1		#2				None	Duplicative false target reflection based on time.
10	18 Jan	0500-8	C	1	Saudi (NFI)	Intercepted by Patriot		1		#2				None	Duplicative false target reflection based on time.
11	18 Jan	0930	C	1	KKIA	Engaged by Patriot		1		#2				None	Duplicative false target reflection. Time noted was for stand-up briefing next morning (ref was briefing slide).
12	20 Jan		?	3	Dhahran/ Riyadh	2 destroyed, 1 possible			3	#14				1	One daily log ref'd - no times. Probable dupe of #14 (based on targets).
13	20 Jan	0235	?	6	Riyadh	5 destroyed/1 impact (tent)					6			None	Probable false target engagements but cannot confirm. No verified Scud launches at noted time. Second of two refs notes no impact.

Table 8. Analysis of CURR Scud Incident Entries

CURR Working Paper Entries							Office of the Special Assistant Analysis								
Serial Nbr	CURR Date	CURR Time	Time = Z or C	Scuds Fired	Reported Target Location	CURR Remarks	1st Ref	Clear Dupes	Likely Dupes	Dupe of	False Target	Wrong Salvo Size	No Match	Event # in Sec V	OSAGWI Remarks
1	17 Jan	0255	?	1	Dhahran	Impact					1			None	Three hand logs reflected Scud activity early 1/17/91. Only coordinates put impact 13 miles NNW of Al Mishab. One log notes "could be artillery." No other sources note this activity. Probable false report based on incoming artillery (rockets?).
2	18 Jan		?	1	Dhahran	Destroyed					1			None	Many sources reported this activity later determined to be reaction to false Patriot radar targets.
3	18 Jan	0030	Z	1	Dhahran	Not engaged		1		#2				None	Refs cited by CURR also indicate successful engagement by Patriots - source of "not engaged" is unknown. Only time in refs was 0300 probably mis-entered as 0030. Further reflection of false target engagements.
4	18 Jan	0135-45	C	1	Dhahran	Destroyed by Patriot		1		#2				None	Refs note times from 0128Z to 0435 (presume C). Further reflection of false target engagements.
5	18 Jan	0225	Z	6	Dhahran	No impact					6			None	Log notes at 0315 (C) Scuds on way to KKIA - most to Israel but possibly one to Dhahran. Another ref notes one Scud intercepted at 0145Z with six more (but no impacts) at 0225Z. Additional false targets.

- "Wrong Salvo Size." Where a CURR incident entry lists a valid attack but includes an incorrect (too large) number of Scuds for the attack, we put the overage in this column (33 reported Scuds);

- "No Match." In a few cases, we could not match a CURR attack entry with any documented event, usually because the entry and its source material lacked key data such as date and time (6 reported Scuds).

- "Event # in Sec V." Where any CURR entry corresponds to an attack we document in the event tables in Section V of this report, we note our serial number from Section V here.

- "OSAGWI Remarks." This final column summarizes our analysis of each entry to help the reader understand our logic and provides other observations on the CURR entries.

Figure 12 below summarizes the numbers of CURR entries that fell in each of the above categories. The 46 valid missile attacks against the KTO correspond to our assessment noted in Section V.

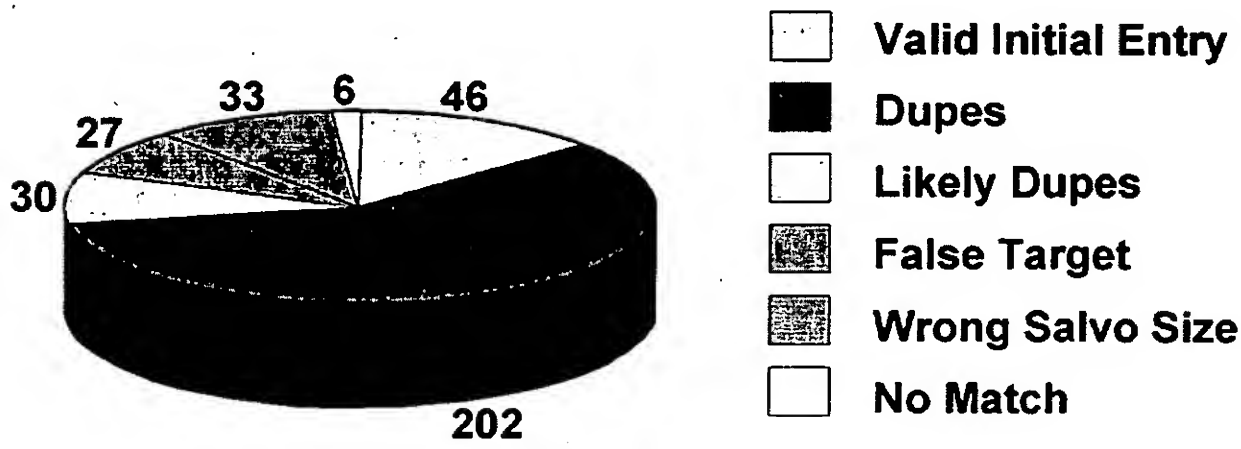

Figure 12. Assessed categories of CURR Scud attack entries

TAB D – Analysis Of CURR Scud Incident List

Release of an internal working paper to several veterans by the Armed Forces Center for Unit Records Research (CURR, formerly Center for Research of Unit Records – CRUR) led to accusations that the Department of Defense had understated the number of Scud firings against the KTO. The working paper listed Scud attacks against Coalition forces. We present below our analysis of this list. In analyzing the list, we based our judgments on careful review of the original operational references used by a CURR officer to construct the list. This material also served as a major resource in preparing the firing incident summaries in Section V. We have provided most of this material, sometimes in redacted form, for review through hyperlinks in the on-line version of this paper on our GulfLINK web site. The sources were too numerous to conveniently cite separately in this tab. Note that this tab and the original CURR compilation address only Scud strikes against the KTO and do not include those against Israel.

Table 8 that follows includes all of the original data from the CURR Scud attack list including date and time of the incident, the number of Scuds reportedly fired, the reported target location, and the CURR analyst's remarks. To this CURR section of the table, we have added an entry number and our estimate of the time zone used in the list (coordinated universal time — Z time — or local time in the KTO — C time, which is three hours later than Z time). The right side of the table adds our assessment of each CURR entry. We placed CURR's missile numbers from each entry into one or more columns based on careful analysis of whether the entry was the first in CURR's list to cover a valid Scud attack on the KTO, a duplication of a valid previous entry, or data at variance with what we believe happened. These last nine columns include:

- "1st Ref." The first time a valid Scud attack shows up in CURR's list. While the attack was valid, the entry sometimes includes erroneous information, and we so note this in our remarks column. (46 Scuds each);

- "Dupes." CURR Scud attack entries that we believe address valid attacks previously listed. However, these additional entries sometimes include more (or less) accurate details on the attack than the first entry, in which case we note this in our remarks. (202 reported missiles);

- "Likely Dupes." The CURR entry appears to address a valid incident covered previously, but the CURR entry and the documents used to create it include details (other than number of Scuds fired) at variance with the bulk of the evidence. This made us somewhat less sure that it was a duplicated entry. (30 missiles);

- "Dupe of." Where an entry appears to involve information about a Scud attack previously listed in the table, the next column notes the entry number of the duplicated CURR entry;

- "False Target." In this column we include entries that were documented as Scuds when in reality they were only false Patriot targets resulting from radar interference (27 reported Scuds);

Date/ Time (1991)	Area	Reports on Test Results or Indications (MULTIPLE PAGE TABLE)
Feb 24 4:32 AM	Riyadh	• No explosion, no injuries. See Table 4.
Feb 24 12:17 PM	KKMC	• No explosion. See Table 5.
Feb 24 9:23 PM	Riyadh	• All clear for chemicals called. Dud warhead confirmed as high explosive by Explosive Ordnance Disposal.[199]
Feb 25 8:32 PM	Dhahran	• High explosive warhead hit barracks with extensive damage and casualties. No chemical casualties.[200]
Feb 26 1:26 AM	Qatar	• Impacted in water 40 miles off Qatar. See Table 3.

[199] Unidentified United States Army organization, "Scud Alert," February 24, 1991; United States Central Command, "NBC Desk Log," February 25, 1991.
[200] United States Army Component United States Central Command, "ARCENT Spot Report," February 25, 1991.

Date/ Time (1991)	Area	Reports on Test Results or Indications (MULTIPLE PAGE TABLE)
Jan 25 10:23 PM	Riyadh	• One warhead explosion demolished Saudi building. • NBC personnel sent to roof of Ministry of Defense and Aviation building (location of United States Central Command Headquarters) after impact about one mile away – reported all clear.[194] • Received all clear from Explosive Ordnance Disposal at strike site.[195]
Jan 26 3:28 AM	Dhahran	• Reporting contains no indications of chemical agent delivery or casualties. See Table 3.
Jan 26 10:46 PM	Riyadh	• Reporting contains no indications of chemical agent delivery or casualties. See Table 4.
Jan 28 10:55 PM	Riyadh	• Reporting contains no indications of chemical agent delivery or casualties. See Table 4.
Feb 3 12:41 AM	Riyadh	• Warhead detonated damaging several buildings. See Table 4 and Significant Incidents.
Feb 8 1:54 AM	Riyadh	• Warhead exploded (indicating high-explosive warhead). See Table 4.
Feb 11 10:20 PM	Riyadh	• Warhead exploded. See table 4. • All clear for NBC contamination reported.[196]
Feb 14 11:45 AM	Hafir Al Batin	• No casualties or chemical munitions use reported.[197] See also Table 5 and Significant Incidents. • Ground and aerial reconnaissance performed and no contamination found.[198]
Feb 16 2:01 AM	Al Jubayl	• Warhead recovered and confirmed as high explosive. See Table 3.
Feb 21 5:06 PM	KKMC	• No chemical agent exposure reported. See Table 5 and Significant Incidents.
Feb 22 2:31 AM	Bahrain	• One of three Scuds hit water. No report of chemical warheads in operational reporting.
Feb 23 4:59 AM	Dhahran	• Reporting contains no indications of chemical agent delivery or casualties. See Table 3.

[194] United States Central Command, "Sequence of Events, 2nd Scud Launch," January 25, 1991.
[195] United States Central Command, "NBC Desk Log," January 26, 1991.
[196] United States Central Command, "SigOps Events," February 11, 1991.
[197] XVIII Airborne Corps, "Intelligence Spot Report Format," Scud Update, February 14, 1991; unidentified United States Army intelligence staff, "Spot Report," February 14, 1991; United States Army Component United States Central Command, "ARCENT Spot Report," February 14, 1991.
[198] 2nd Armored Cavalry Regiment, "Significant Events from Daily Log," March 6, 1991; VII Corps, "NBC Operations Summary," Appendix 2, undated.

TAB C – Chemical Evidence – Scud Incidents In KTO

Table 7. Chemical Warfare Agent Evidence

Date/ Time (1991)	Area	Reports on Test Results or Indications (MULTIPLE PAGE TABLE)
Jan 20 9:43 PM	Dhahran	• Numerous M256 kit, M8A1 alarms, and Chemical Agent Monitor (CAM) tests/checks produced negative results.[185] • Impact was assessed as high explosive.[186]
Jan 21 12:29 AM	Dhahran	• Fox nuclear-biological-chemical reconnaissance vehicles detected no chemical contamination.[187]
Jan 21 12:42 AM	Riyadh	• At least two Scuds exploded on impact. See Table 4 and Selected Incident detail. • No confirmation of nuclear-biological-chemical contamination. All clear reported.[188]
Jan 21 10:18 PM	Dhahran	• Struck in water – no damage/casualties reported.[189]
Jan 22 3:41 AM	Riyadh	• No casualties or damage. See Table 4.
Jan 22 7:10 AM	Dhahran	• Numerous negative CAM results. However, one CAM produced one-bar (very low concentration) for G nerve agent, but later checks with M256 kit proved negative.[190]
Jan 23 10:54 PM	Dhahran	• An M8A1 alarm did not alert.[191]
Jan 23 10:54 PM	Riyadh	• United States/Saudi police desk reported no nuclear-biological-chemical alarms. NBC reported all clear. Then Saudis reported mustard reading in area, but Explosive Ordnance Disposal team checked and found nothing.[192] • French investigated one suspected impact area but found no crater or contamination.[193]

[185] Unidentified United States Army organization, "G-3 Spot Report," January 20, 1991; 1st Tactical Fighter Wing (Provisional), "Log of Events," January 20, 1991.
[186] United States Central Command, "NBC Desk Log," January 20, 1991.
[187] Unidentified United States Army organization, "Desert Shield G3-NBC Significant Events," undated.
[188] 2nd Armored Cavalry Regiment, "Daily Staff Journal or Duty Officer's Log," January 21, 1991; United States Central Command, "NBC Desk Log," January 21, 1991; unidentified United States Army organization, "Desert Shield G3-NBC Significant Events," undated.
[189] VII Corps air defense element, "Daily Staff Journal or Duty Officer's Log," January 21, 1991.
[190] 1st Tactical Fighter Wing (Provisional), "Log of Events," January 22, 1991.
[191] 1st Tactical Fighter Wing (Provisional), "Log of Events," January 23, 1991.
[192] United States Commander-in-Chief United States Central Command, "Daily Staff Journal Sig Ops Events," January 23, 1991; 74th Explosive Ordnance Disposal Detachment, "Explosive Ordnance Incident Report," January 23, 1991.
[193] Unidentified United States Army rear command post, "Message Form/CTOC Journal Sheet," January 23, 1991.

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management/command control and communications centers. The multifunction phased array radar provides surveillance, target detection and tracking, and missile guidance support. The trailer-mounted launcher holds four Patriot missiles in the configuration used most in Operation Desert Storm. The missile has a blast fragmentation warhead.[181] Each missile weighs 2,200 pounds and has a range of nearly 43 miles. When launched, the missile turns toward the target and enters the radar beam. A computer on the ground then directs the missile toward the target. In the terminal phase, the missile's internal radar receiver guides it to interception.[182]

VX — V-series nerve agent. Chemical Name: O-ethyl-S-(2-isopropylaminoethyl)methyl phosphonothiolate.[183]

Z time — Coordinated universal time (UTC), also called "zulu time," formally Greenwich Mean Time. The time in the time zone centered on the prime meridian and used by United States forces as a standard time in, for example, electronic messages because it puts global forces on the same clock.[184]

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M8A1 Chemical Alarm

The M8A1 is an automatic chemical agent detection and warning system designed to detect the presence of nerve agent vapors or inhalable aerosols. The M8A1 will automatically signal the presence of the nerve agent in the air with both an audible and visual warning. The United States military fielded the M8A1 to replace the wet chemical M8 detector—which eliminated the M229 refill kit, the logistic burden, and associated costs. The M8A1 operates in a fixed, portable, or vehicle mounted configuration.[178]

Mission Kill

Patriot intercepts that do not disable the ballistic missile warhead but nevertheless minimize damage on the ground. There were two types of mission kills. One involved low yield kills in which the Patriot damaged the ballistic missile warhead to the point that either it only burned at ground impact or it exploded with greatly reduced force. The other involved diversion in which a Patriot deflects the ballistic missile from its initial path and it impacted with no significant ground damage to personnel or major structures.[179]

Mission Oriented Protective Posture (MOPP)

Mission oriented protective posture (MOPP) is a flexible system used to direct the wearing of chemical protective garments and mask—a system that balances mission requirements with the chemical warfare agent threat. Wearing chemical protective garments and mask provides individuals protection against most known chemical warfare agents, biological agents, and toxins. At MOPP Level 0 servicemembers carry their protective mask and keep their remaining MOPP gear readily available (e.g., within the work area, fighting position, living space, etc.) At MOPP Level 1, servicemembers wear their overgarment and carry the rest of their MOPP gear. At MOPP Level 2, servicemembers wear their overgarments and overboots while carrying the mask with hood and gloves. At MOPP Level 3, servicemembers wear their overgarment, overboots, and mask with hood, but not the gloves. At MOPP Level 4, servicemembers wear all their MOPP gear. Commanders can raise or lower the amount of protection through five levels of MOPP. In addition, commanders, under certain situations, can exercise a mask-only option.[180]

Patriot Surface-to-Air Missile System

The Patriot is a long-range, all-weather, high and low altitude system designed to defeat advanced aircraft, tactical ballistic missiles, and cruise missiles. It can engage multiple, simultaneous targets. The Patriot Fire Unit consists of a radar, launchers, missiles, and battle

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[178] Brletich, Nancy R., Mary Jo Waters, Gregory W. Bowen, Mary Frances Tracy, Worldwide Chemical Detection Equipment Handbook, Chemical and Biological Defense Information Analysis Center, October 1995, p. 412.

[179] Boley, Ray M. "Patriot Performance Assessment in Desert Storm Roadmap (U)," CAS, Incorporated for United States Army Missile Command, July 25, 1991 (S), p. 3.

[180] United States Army Field Manual 3-4, United States Marine Corp Fleet Marine Force Manual 11-09, "NBC Protection," February 21, 1996, p. 2-2 to 2-4.

Fox Nuclear, Biological Chemical Reconnaissance System

The Fox vehicle is a six-wheeled, light armored vehicle designed primarily for reconnaissance of liquid chemical warfare agent hazards. On-board chemical warfare agent detection capabilities include the MM-1 mobile mass spectrometer (primary detection device), the M43A1 chemical agent detector (an integral component of the M8 alarm system), and the M256A1 chemical agent detector kit. The Fox also has two radiation detectors. The Fox does not provide any biological warfare agent detection capability, but it does protect the crew from biological hazards, and it allows the crew to mark areas of potential hazard and safely take samples for laboratories to analyze for biological hazards.[176]

M256 Chemical Warfare Agent Detector Kit

In the field, the M256-series chemical warfare agent detector kit is referred to simply as the M256 kit. The portable, expendable M256 kit can detect and identify hazardous concentrations of blister, blood, and nerve agents. The M256 kit is used after a chemical warfare agent warning to test for and confirm the presence and type of chemical warfare agent, and to determine if it is safe to unmask. The M256A1 kit has replaced the M256 kit. The only difference between the two kits is that the M256A1 kit will detect lower levels of nerve agent. United States forces used both the M256 kit and the M256A1 kit during the Gulf War.

Some smokes, high temperatures, standard United States decontamination solution number two (DS2), and petroleum products may cause false readings. Sampling in smoke from burning debris may produce inaccurate results.[177]

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[176] United States Army Technical Manual 3-6665-342-10, "Operator's Manual, Nuclear-Biological-Chemical Reconnaissance System (NBCRS) Fox XM93," Washington, DC, Change 2, April 21, 1995, p. 1-2, 1-6; Testimony of Fox subject matter expert, Mr. Richard Vigus, CBDCOM, before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, May 7, 1997; United States Army Field Manual 3-101-2, "NBC Reconnaissance Equipment and Organizations," August 10, 1994, p. 2-1.

[177] Brletich, Nancy R., Mary Jo Waters, Gregory W. Bowen, Mary Frances Tracy, Worldwide Chemical Detection Equipment Handbook, Chemical and Biological Defense Information Analysis Center, October 1995, p. 430-431. Copies of the Worldwide Chemical Detection Equipment Handbook may be purchased from the CBIAC. To order, please contact the CBIAC Administrator, via phone (410-676-9030), fax (410-676-9703), e-mail (cbiac@battelle.org), or use the interactive request form on the CBIAC web site: www.cbiac.apgea.army.mil (as of October 19, 1999). See also Special Assistant for Gulf War Illnesses, "M256 Series Chemical Agent Detector Kit" (Information Paper), web site www.gulflink.osd.mil/m256/, July 23, 1999.

OSAGWI.....Office of the Special Assistant for Gulf War Illnesses
Refs.....references
S2/S-2.....intelligence officer or staff
SigOps.....significant operations
SITREP.....situation report
SRBM.....short-range ballistic missile
TBM.....tactical ballistic missile
UDMH.....unsymmetrical dimethylhydrozine
UNSCOM.....United Nations Special Commission
USARCENT.....United States Army Component United States Central Command
USCINCCENT.....United States Commander-in-Chief Central Command

Glossary

B TIME — The time in the time zone located two time zones east of the time zone centered on the prime meridian. This time zone included Israel.

CEP — Circular error probable. An indicator of the delivery accuracy of a weapon system, used as a factor in determining probable damage to a target. It is the radius of a circle within which half of a missile's projectiles are expected to fall.[174]

C TIME — The time in the time zone located three time zones east of the time zone centered on the prime meridian. This time zone included the KTO.

DSP — Defense Support Program uses a satellite-borne system with infrared detectors to sense heat from missile plumes against the earth background. It detects and reports in real time missile launches, space launches, and nuclear detonations. During Desert Storm, DSP detected the launch of Iraq's Scud missiles and permitted timely warning to civilian populations and coalition forces in Israel and the KTO.[175]

[174] Defense Technical Information Center, DoD Dictionary of Military Terms, "Circular Error Probable," web site: www.dtic.mil (as of September 15, 1999).
[175] Federation of American Scientists, "Defense Support Program," web site: www.fas.org (as of September 30, 1999).

TAB A – Acronyms, Abbreviations, and Glossary

This tab provides a listing of acronyms and abbreviations found in this report. Additionally, the Glossary section provides definitions for selected technical terms that are not found in common usage.

Acronyms and Abbreviations

ADA ..... air defense artillery
ARCENT ..... United States Army Component United States Central Command
BDA ..... battle damage assessment
Bn ..... battalion
BW ..... biological warfare
CENTAF ..... United States Air Force Component United States Central Command
CEP ..... circular error probable
CIA ..... Central Intelligence Agency
CINC ..... commander-in-chief
CTOC ..... corps tactical operations center
CURR ..... Center for Unit Records Research
CW ..... chemical warfare
CWA ..... chemical warfare agent
DIA ..... Defense Intelligence Agency
DISUM ..... defense intelligence summary
DoD ..... Department of Defense
DS ..... Desert Storm
DSP ..... Defense Support Program
DTG ..... date time group
EOD ..... explosive ordnance disposal
Gen ..... general
GPALS ..... Global Protection Against Limited Strikes
HTH ..... calcium hypochlorite
INTSUM ..... intelligence summary
IRFNA ..... inhibited red fuming nitric acid
IZ ..... 2-letter shorthand for Iraq
JTF ..... joint task force
KG ..... kilogram
KKMC ..... King Khalid Military City
KTO ..... Kuwait theater of operations
MOPP ..... mission oriented protective posture
NATO ..... North Atlantic Treaty Organization
NESA ..... (CIA office) Near East South Asia
NBC ..... nuclear biological chemical

Scud attack entry. For example, if separate reports covered an attack, one using coordinated universal (Z) time and the other using local time in the KTO (C time - three hours difference) the CURR report generated two entries, one for each time, even if all the other details coincided. The officer that prepared the compilation knew the entries involved duplications, but CURR released the list before they could scrub it to consolidate different reports of the same incident. Our analysis of CURR's incident record revealed massively redundant counting based on various second-hand accounts of individual attacks and included false alarms where Iraq launched no Scuds. When we subtracted these duplications and false alarms, the total number of attacking Scuds very closely matched the counts published by other expert sources. See an accounting of the CURR list at Tab D.

- Iraq worked to develop extended-range Scud variants capable of delivering both chemical and biological warfare agents. As of early 1991, they had produced and filled such warheads on Scuds. However, the evidence suggests that they could not carry out an effective attack with these weapons because of fusing and flight stability problems.

- We uncovered no convincing evidence that Iraq fired Scuds with chemical or biological agent warheads at Coalition forces or Israel. Technical problems, threats of retaliation, and risk-benefit considerations may have affected Iraq's decision not to employ them.

- A substantial proportion of the Al Hussein Scud models spontaneously broke up on reentry, probably due to faulty design and unstable flight characteristics.

- During disintegration on reentry or impact, some Scuds released a yellow, red, or brown cloud containing corrosive inhibited red fuming nitric acid. Observers sometimes mistakenly believed these releases of oxidizer were releases of chemical warfare agents. While not nearly as toxic as chemical warfare agents, IRFNA and accompanying nitrogen oxide decomposition products can cause, as described previously, distressing symptoms in exposed people.

- The extended-range Scuds fired by Iraq demonstrated even poorer accuracy than the original Soviet design but had modest success as a terror weapon against large population concentrations. As the Scud attacks progressed and it became apparent that Iraq had used no chemical or biological agent warheads, the missiles became less effective as a terror weapon.

- Iraq probably retains some Scud-type missiles and may be able to produce more.

- In 1992, the Director of Central Intelligence stated that Iraq retained "perhaps hundreds" of missiles, and his successor estimated the residual force at 100-200 missiles.[167]

- Israeli sources indicated Iraq may have as many as 100 Scuds of all versions.[168]

- In 1995, Iraq eventually admitted to the United Nations Special Commission that in 1987 it had begun a full-scale program to indigenously manufacture Al Hussein Scuds largely from scratch and had established specialized factories for this purpose. Iraq planned eventually to produce 1,000 missiles, but it claimed that by January 1991 they had failed to produce a single operational missile.[169]

- In mid-1996, a general officer defector from Iraq said that he believed Saddam Hussein had retained some 40 Scud-type missiles.[170]

- By 1996, UNSCOM concluded that Iraq had produced 80 Scud-like missiles indigenously that inspectors could not locate.[171] After UNSCOM unwillingly withdrew from Iraq in 1998, some estimated that Iraq could resume production of Al Hussein missiles within one year.[172]

- According to a United States government white paper in 1998, Iraq maintained a small force of Scud-type missiles and may have pieced together Scuds by integrating original guidance and control systems it concealed from UNSCOM with parts produced in Iraq.[173]

X. SUMMARY OF OBSERVATIONS

The results of our Scud missile research and analysis can be summarized as follows:

- During the Gulf War, Iraq attacked with approximately 88 Scuds, almost all of them Al Hussein models, with 46 striking in the KTO and 42 in or near Israel. Several more firings probably resulted in early in-flight failures within Iraq.

- An internal working paper produced and released to veterans by the Center for Unit Records Research (CURR) included 179 entries appearing to involve approximately 344 missiles. In it, CURR listed each variation in attack detail, however minor, as a separate

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[167] Isby, David C., "The Residual Iraqi 'Scud' Force," *Jane's Intelligence Review*, Vol. 7, Nbr 3, p. 115.
[168] Centre for Defence and International Security Studies, "National Briefings: Iraq," web site: www.cdiss.org (as of July 29, 1999).
[169] United Nations Special Commission, "UNSCOM's Comprehensive Review," Appendix 1, Status of the Material Balances in the Missile Area, and cover letter, January 25, 1999, web site: www.un.org (as of March 10, 2000).
[170] Centre for Defence and International Security Studies, "National Briefings: Iraq," web site: www.cdiss.org (as of July 29, 1999).
[171] Federation of American Scientists, "UNSCOM and Iraqi Missiles," web site: www.fas.org (as of May 13, 1999).
[172] Center for Nonproliferation Studies, "Weapons of Mass Destruction in the Middle East," Iraq, on site cns.miis.edu (as of April 24, 2000).
[173] United States Government White Paper, "Iraq Weapons of Mass Destruction Programs," February 13, 1998.

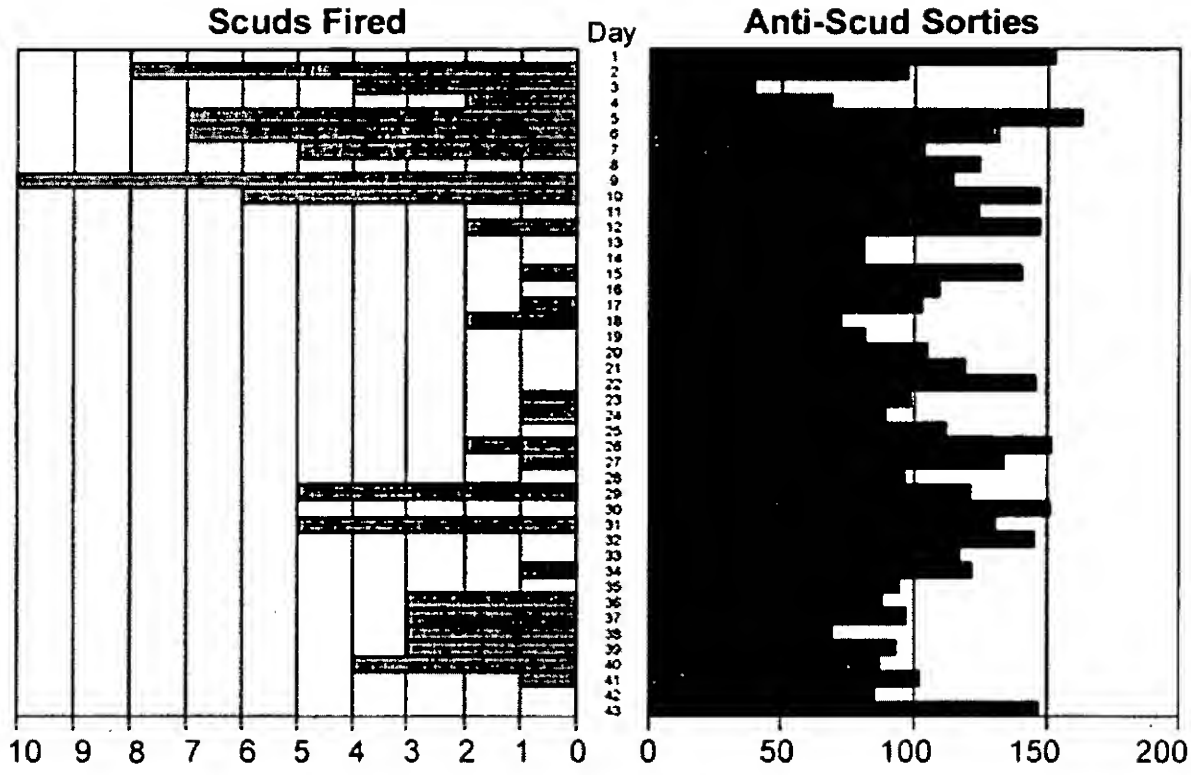

Figure 11. Scuds fired and anti-Scud sorties flown by day[164]

Scud units in the field proved difficult to locate and hit. What became known as "the Great Scud Hunt" had questionable operational effectiveness. As the United States Gulf War Air Power Survey noted, most, and possibly all of the 100 mobile launchers reported struck by Coalition aircraft appeared later to have involved decoys, other vehicles, or other objects that presented Scud-like signatures.[165]

IX. THE RESIDUAL THREAT

The United Nations Special Commission supervised destruction of 48 Scuds plus additional components and found evidence that Iraq unilaterally destroyed at least another 83 missiles unsupervised.[166] However, many estimates point to a substantial residual Scud inventory. Some data points from various sources include:

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[164] For Scuds fired, see section V. Anti-Scud sorties based on Department of Defense Final Report to Congress, "Conduct of the Persian Gulf War," April 1992, p. 165.

[165] Gulf War Air Power Survey, Volume II, Part I, Washington, DC: United States Government Printing Office, 1993, p. 189.

[166] United Nations Special Commission, "UNSCOM's Comprehensive Review," Annex A, Status of the Material Balances in the Missile Area, and cover letter, January 25, 1999, web site: www.un.org (as of March 10, 2000).

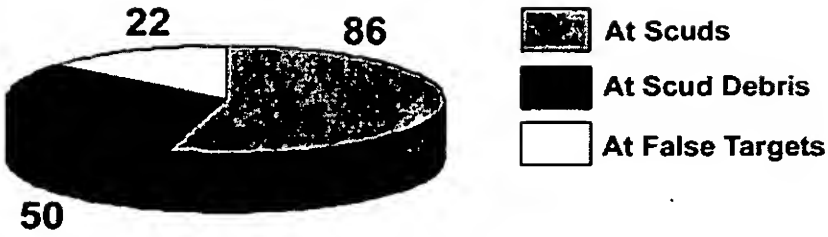

Figure 10. Patriots expended by target type

Part of the Coalition strategy for dealing with Scuds involved pre-planned air strikes against associated production and storage facilities.[161] These strikes were concentrated during the early part of the air campaign.[162]

Another component of United States reaction to protect Coalition forces was Scud hunting. Beginning with the initial Scud attacks against Israel on January 18, 1991, and Saudi Arabia on January 20, 1991, United States forces came under enormous pressure to do something about the immediate Scud threat. Reportedly, the United States leadership in Washington, DC, focused on the potential diplomatic and political fallout from Scuds, while most senior air commanders believed that Scuds "did not represent a particularly credible military threat" (emphasis original). As Air Force Lieutenant General Charles A. Horner, commander of the United States Air Force Component United States Central Command observed, the Scud was "a lousy weapon."[163]

Nevertheless, the Coalition diverted considerable resources to attempt to neutralize Iraq's Scuds. Figure 11 displays in parallel graphs the number of total sorties dedicated to counter-Scud operations of all kinds (right) and the number of Iraq's Scuds attacking the KTO and Israel (left). Day 1 was January 17, 1991, and Day 43 was February 28, 1991.

[161] Gulf War Air Power Survey, Volume II, Part I, Washington, DC: United States Government Printing Office, 1993, p. 124, 149, 151.
[162] Testimony of General H. Norman Schwartzkopf before the Senate Committee on Veterans Affairs, January 29, 1997, the United States Senate web site: www.senate.gov (as of June 11, 1999).
[163] Gulf War Air Power Survey, Volume II, Part I, Washington, DC: United States Government Printing Office, 1993, p. 178, 182, 184.

VIII. COALITION RESPONSE TO SCUD THREAT

The Coalition took strong actions to protect forces and civilians and diminish the impact of Scud attacks. The Coalition considered Scuds a military and psychological threat to their forces, populations, and interests. Scud threat reduction efforts went forward on several fronts and included expanded surveillance and warning, deploying Patriot surface-to-air missiles with some ballistic missile intercept capability, air strikes against production and storage facilities, and attempts to destroy Scud units in the field before or after they launched missiles.[154]

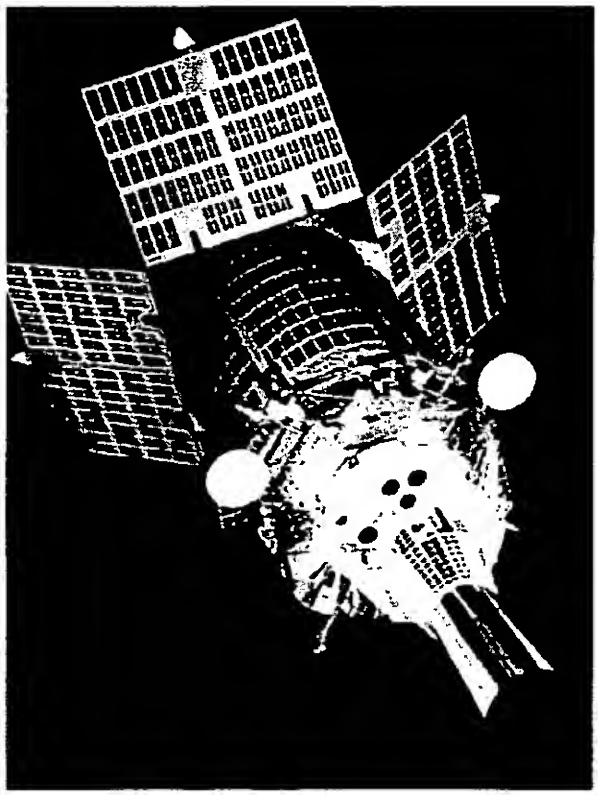

Figure 9. DSP surveillance satellite[159]

The key component of the Scud alert process was the Defense Support Program surveillance satellites (see Figure 9)[155] that identified launches by detecting the infrared energy from a rocket in powered flight.[156] During Operation Desert Storm, United States Space Command quickly assessed the downlinked infrared detections and rapidly passed alert data to United States Central Command and other allies.[157] According to one source, military radars in the region could track missiles and aid in the extrapolation process to identify potential target areas.[158]

In another response to the Scud threat, the United States deployed Patriot surface-to-air missile units to Israel, Saudi Arabia, and Bahrain. Tab A includes a Patriot system description. Figure 10 summarizes the targets at which post-war analysis determined the Patriots fired.[160]

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[154] Department of Defense Final Report to Congress, "Conduct of the Persian Gulf War," April 1992, p. 73, 97, 166, 168, 169.

[155] Department of Defense Final Report to Congress, "Conduct of the Persian Gulf War," April 1992, p. 177.

[156] United States Space Command, "Defense Support Program," web site: www.spacecom.af.mil (as of September 30, 1999).

[157] Hoffman, Timothy, "Space Capabilities Vastly Improved Since Gulf War," Air Force Space Command Public Affairs, Peterson Air Force Base, CO, March 1998; Cooper, Henry F., "Limited Ballistic Missile Strikes. GPALS Comes Up with an Answer," *NATO Review*, June 1992, web site: www.nato.int (as of July 27, 1999).

[158] Broad, William J., "Iraqis Using Clouds to Cover Scud Firings, Meteorologists Say," *New York Times*, January 25, 1991, p. 10.

[159] Federation of American Scientists, "Defense Support Program," web site: www.fas.org (as of September 30, 1999).

[160] Boley, Ray M. "Patriot Performance Assessment in Desert Storm Roadmap (U)," CAS, Incorporated for United States Army Missile Command, July 25, 1991 (S), p. D-2.

VII. SCUD OXIDIZER INCIDENTS

As Israeli officials pointed out to us, when reentering Scuds were intercepted or broke up on their own, they sometimes released a yellow-to-reddish-to-brownish cloud of the Scud's residual propellant oxidizer. People on the ground observing these clouds voiced concerns that the airborne releases involved chemical warfare agent. Incoming Al Hussein missiles contained about 300 pounds of residual oxidizer and 100 pounds of fuel. The oxidizer and accompanying oxides of nitrogen were dangerous in their own right and caused a range of symptoms in people exposed on the ground.[149]

Iraq's Scud oxidizer, inhibited red nitric acid (IRFNA), can cause deep and painful burns on the skin or in the lungs. When inhaled, the oxidizer and its nitrogen oxide decomposition products can produce immediate or delayed symptoms including throat dryness, cough, headache, dizziness, anxiety, extreme fatigue, nausea, vomiting, chest pain, labored breathing, inflammation of the lungs, choking, fluid build-up in the lungs, and suffocation, depending on the extent of exposure.[150] In interviews with our investigators, or during testimony before government panels, Gulf War veterans reported a variety of symptoms consistent with oxidizer exposure. Extracted from their accounts, these symptoms included tearing eyes, runny noses, nausea, vomiting, dizziness, sleeplessness, headaches, and blurred vision.[151] Kerosene, the fuel component of Iraq's Scud propellants, also escaped during breakups, but kerosene is not particularly toxic, even after acute exposure.[152]

Readers wanting additional information on Scud oxidizer should consult our information paper on IRFNA.[153]

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[149] Central Intelligence Agency, "Gulf War Syndrome," July 1995; Central Intelligence Agency, "CIA Report on Intelligence Related to Gulf War Illnesses," August 2, 1996. See also bullets in this section.

[150] Central Intelligence Agency, "Gulf War Syndrome," July 1995; Howard Hughes Medical Institute, "Laboratory Chemical Safety Summaries," Nitric Acid, web site: www.hhmi.org (as of May 8, 2000); Proctor, Nick H., et al., Chemical Hazards of the Workplace, third edition, Van Nostrand Reinhold, New York, 1991, p. 425-426.

[151] Testimony of Ms. Harmon-Davis before the Presidential Advisory Committee on Gulf War Veterans' Illnesses, Washington, DC, May 1, 1996; Lead Sheet #19849, Interview of 55th Support Battalion supply soldier, October 10, 1998, p. 1; Lead Sheet #9462, Interview of 10th Battalion soldier, December 18, 1997, p. 1; Lead Sheet #16471, Interview of Army Support Group operations, training, and procurement officer, May 15, 1998, p. 2, 5; Lead Sheet #20899, Interview of 551st Transportation Company soldier, December 29, 1998, p. 1,2; Lead Sheet #17229, Interview of Navy master chief of motor vessel Baugh, June 10, 1998, p. 1; Lead Sheet #8802, Interview of 703rd Provisional Boat Company engineer-oiler, June 25, 1997, p. 2.

[152] European Oil Company Organization for Environment, Health, and Safety, "Kerosine," web site: www.concawe.be (as of January 27, 2000).

[153] Special Assistant for Gulf War Illnesses, "Inhibited Red Fuming Nitric Acid," (Information Paper), web site www.gulflink.osd.mil/irfna/, August 3, 1999.

A Fox chemical reconnaissance vehicle searched for evidence of chemical warfare agent but found none.[144] One chronology stated that the explosions happened when a friendly aircraft released bombs into an ordnance jettison area.[145] We found only one contemporaneous record that indicated (correctly) that the reports of ballistic missiles launched at Dhahran on the 18th were erroneous.[146]

Despite the flurry of Patriot false targets early in the war (some interspersed with real attacks), we found no evidence that Patriots engaged false targets after January 23, 1991 (presumably because of the equipment and software fixes). Figure 8 shows how the 20 false target detections break down by day based on research of unclassified and declassified operational reporting.[147] Patriots did not launch missiles at every false target, but one report indicated that Patriot batteries fired a total of 22 missiles at false targets. In another report, an official admitted that the number was 24.[148]

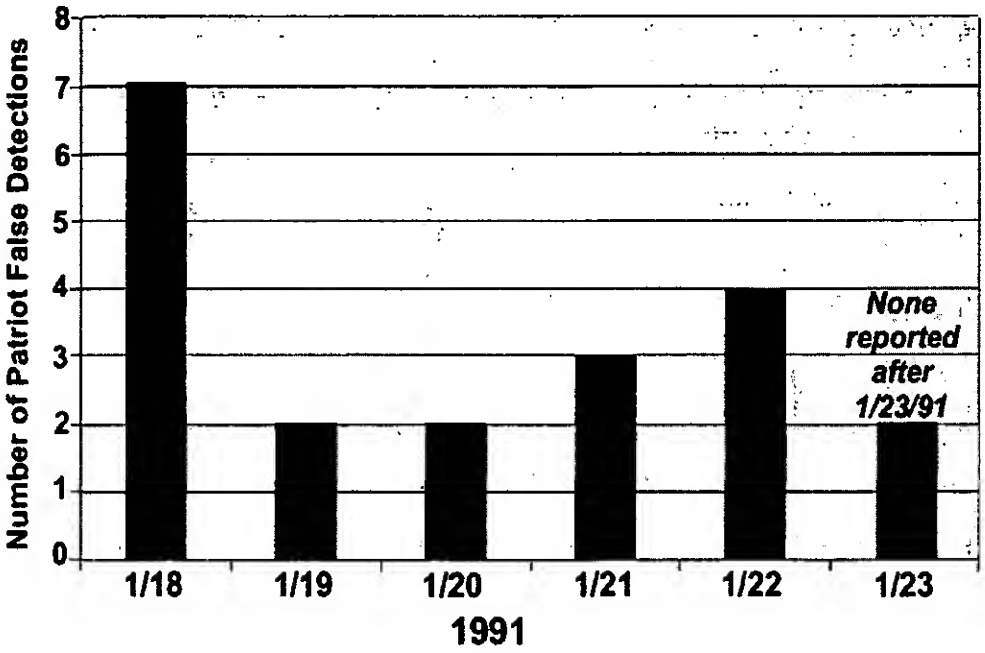

Figure 8. False Patriot detections by date

[144] United States Army Component United States Central Command, "Unconfirmed Spot Report," memorandum for command group, January 18, 1991.
[145] 1st Calvary Division, "AAR 1st Calvary Div Command Report," April 10, 1991.
[146] United States Central Command, "NBC Desk Log," January 18, 1991.
[147] Based on messages and logs referenced in Section V and too numerous to repeat here.
[148] Boley, Ray M. "Patriot Performance Assessment in Desert Storm Roadmap (U)," CAS, Incorporated for United States Army Missile Command, July 25, 1991 (S), p. D-2; Lovece, Joseph, "Electronic Noise from U.S. Gear Prompted Errant Patriots," *Defense Week*, September 28, 1992, p. 1.

human judgment or adjustments in procedures. In addition to the detections graphed, United States Space Command generated five false alarms from December 25-30, 1990, three the result of live ballistic missile test firings by Iraq.[139]

B. Patriot False Target Detections

According to information published after the Gulf War, a problem with the Patriot radar system caused Patriot missiles to fire at phantom targets. In September 1992, an Army official admitted that electronic signals, or noise, emitted by a variety of United States systems caused computer problems and accidentally launched Patriot missiles in the first week of the war. The Patriot's radar system processed these signals as the result of software flaws and a design that left the back of the radar unit open to stray signals. These signals came from the airborne warning and control system aircraft, radar jamming pods on fighters, test equipment, airport radars, and communications systems. Software changes and makeshift shrouds for the backs of Patriot radars eventually resolved the problem.[140] During the early stages of the air war that began on January 17, computers automatically directed the Patriot missile batteries' threat responses. Soldiers in Patriot units did not have a role in the fire, no-fire decisions. Patriot units later revised the procedures, and changed to a manual mode of engagement that allowed operators to decide when to fire.[141]

The first actual ballistic missile attack against the KTO occurred against the Dhahran area at 9:43 PM on January 20, 1991. However, false targets involving Patriot reactions began on January 18, 1991, without warnings from national surveillance assets. Veterans aware of these engagements believed, at least at the time, that incoming missiles threatened them. Most reports did not identify the January 18th incidents as reactions to Patriot false targets until after the war when the discrepancy became public knowledge. For example, during the war, one Army document noted for the 18th that Patriots intercepted a single Scud in the Dhahran area.[142] Alpha Battery, 2nd Battalion, 7th Air Defense Artillery got credit for a first successful Scud intercept. An element of the XVIII Airborne Corps reported seeing a Scud missile heading south. Three powerful explosions occurred over Dhahran Air Base. This report claimed that three missiles had been fired at Dhahran. The same document indicated that Patriots engaged one incoming missile but that another hit Khobar, an area where United States forces were billeted. The entire Dhahran area was reported at MOPP Level four with lower MOPP levels ordered further west.[143]

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[139] The December 25, 26, 27, 29 and 30, 1990, false alarms were based on XVIII Airborne Corps, "XVIII Airborne Corps Operation Desert Storm Chronology," December, 1990.

[140] Lovece, Joseph, "Electronic Noise from U.S. Gear Prompted Errant Patriots," *Defense Week*, September 28, 1992, p. 1, 13.

[141] Simon, Alexander, "The Patriot Missile. Performance in the Gulf War Reviewed," July 15, 1996, Center for Defense Information, web site: www.cdi.org (as of October 1, 1997); Department of the Army, "Patriot TBM Engagement Modes," executive summary, January 24, 1991.

[142] VII Corps, "Defense of the Wadi Al Batin," p. 91; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 47.

[143] XVIII Airborne Corps, "XVIII Airborne Corps Operation Desert Storm Chronology," January 1991; 1st Brigade, 1st Cavalry Division, "1st Brigade Chronology," Annex B, undated.

A mobile Army surgical hospital (MASH) chronology includes the following for January 17th:

> The 807th MASH has entered the war, and suddenly loudspeakers begin to blare, "SCUD alert ... MOPP level four" ... we all scurry into our MOPP gear ... The lights are out, now, and we have been previously informed that the Saudis think a SCUD can only penetrate the top two floors of our building. In total darkness, punctuated only by the red-lensed flashlight beams, all 250 members of the 807th troop down three flights of stairs. As we occupy the empty apartments, each person sits on the floor, alone inside his mask except for his or her thoughts and fears. For 2 long hours we breathe claustrophobic air in hot chemical suits, until, with dawn, we hear, "ALL CLEAR, MOPP level zero." ... We later find out that radar confused our own returning B-52's with Scuds. Fortunately, we learn that after the war has ended.[138]

Figure 7 summarizes the false alarms during Operation Desert Storm. These false alarms declined in frequency after the first eight days of the war. The decline possibly reflected refined

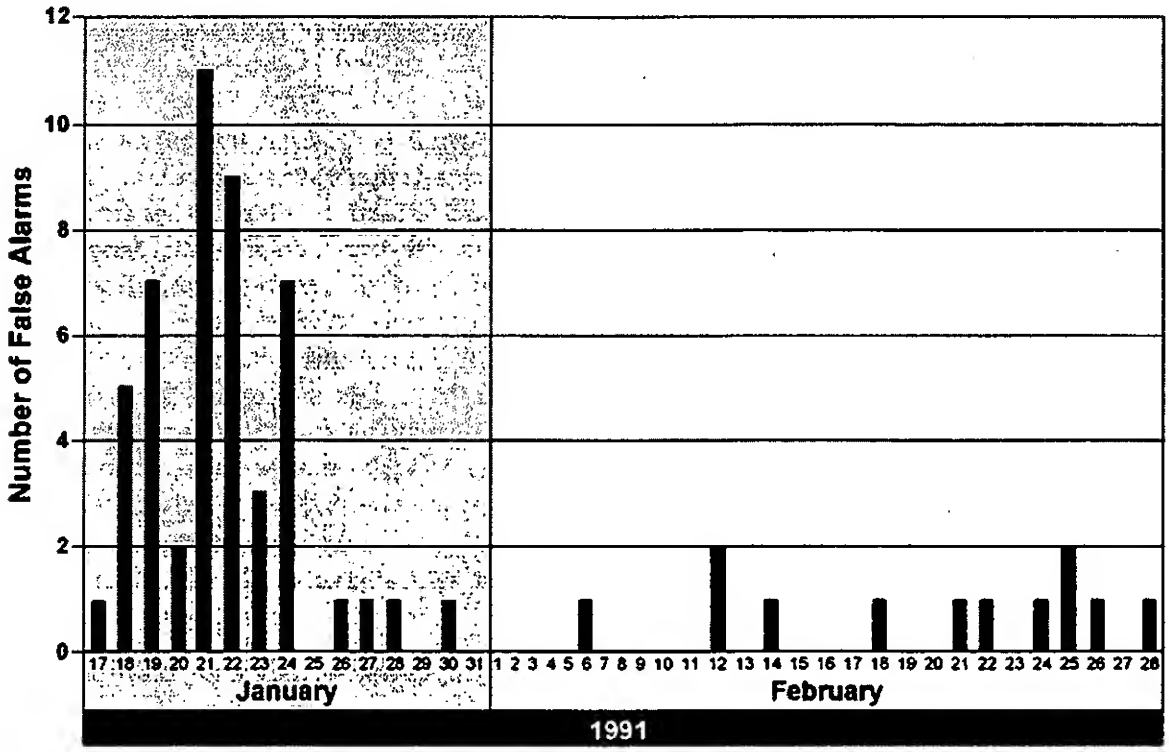

Figure 7. False alarms during Operation Desert Storm

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[135] United States Army Component United States Central Command operations staff, "Daily Staff Journal or Duty Officer's Log," January 17, 1991.

[136] 513th Military Intelligence Battalion, "Foreign Material Intel Bn Section III G I," undated.

[137] United States Central Command, "NBC Desk Log," January 17, 1991.

[138] 807th Surgical Hospital (Mobile Army), "The 807th Surgical Hospital (Mobile Army) and its Contributions and Adventures during Operation 'Desert Shield/Storm,'" undated.

VI. FALSE ALARMS AND FALSE TARGETS

Coalition forces in the Kuwait theater of operations responded not only to actual Scud launches but also to many false reports of Scud attacks generated by early warning surveillance assets, intelligence reports, or because Patriots fired at false targets.

A. False Alarms

After a thorough review of ballistic missile incident accounts from Operation Desert Storm, we determined that at least 60 false alarms were logged in the KTO[131] (in addition to the Patriot false target detections addressed separately below). None of these 60 alarms documented an actual missile attack, but they may have created the impression that such attacks occurred more frequently than was the case. Even though many of these alerts were cancelled within minutes, many servicemembers and civilians took appropriate measures, donned chemical protective gear, and sought shelter. We believe (because alerts were canceled promptly) that misinterpretation of initial infrared (heat-source) detections by satellites led to most of these false alarms. At least two other false alarms came from detection of signals from a radar associated with Scud operations (it tracks weather balloons to determine winds aloft).

The United States operations, intelligence, and space communities collectively made history when they developed a system to provide warning of Iraq's ballistic missile launches to the entire KTO (and Israel) within minutes.[132] This system relied primarily on space-based infrared surveillance. However, across any combat theater, there are many non-missile infrared sources including exploding bombs, high intensity flares, demolitions of weapons storage sites, and other sudden heat-producing events capable of registering on infrared-sensitive devices. Because warning time was at a premium, some early alerts proved false, but the goal was always to notify quickly to protect lives.[133]

On January 17th, the day the air campaign began, a Scud warning shortly after 4:00 AM put many bases and units in the Dhahran area into MOPP Level 3 (full protective gear except gloves – see glossary in Tab A).[134] Reports even noted confirmed missile impacts in the area[135] and Scud fragments collected.[136] The warning was eventually cancelled.[137]

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[131] There were too many source documents to conveniently cite here. We cited most of them elsewhere in this paper, such as United States Central Command, "NBC Desk Log;" VII Corps, "Major Subordinate Command Historical Reports -- Task Force 8-43 AD;" VII Corps, "Daily Log," January-February 1991; and other command post logs and journals.

[132] Department of Defense, Final Report to Congress, "Conduct of the Persian Gulf War," April 1992, p. 177.

[133] Schubert, Frank N. and Theresa L. Kraus, eds., "The Whirlwind War, the United States Army in Operations Desert Shield and Desert Storm," Appendix A, Center of Military History, United States Army, Washington, DC, 1995, p. 245-246; Department of Defense, Final Report to Congress, "Conduct of the Persian Gulf War," April 1992, p. 176-177.

[134] Unidentified United States Army air defense element message, "Message Form/CTOC Journal Sheet," January 17, 1991; XVIII Airborne Corps, "XVIII Airborne Corps Operation Desert Storm Chronology," January 1991.

States housing area. A United States airman in the housing area remembered the debris falling around him but recalled no injuries.[126]

F. Scud Incidents in Israel

Iraq fired 42 Scuds that reached Israel or nearby areas of Jordan beginning on January 18, 1991. Iraq launched these missiles from Western Iraq against three general target areas – Tel Aviv, Haifa, and the Negev Desert in Southern Israel, specifically, Dimona where Israel had a nuclear facility.[127] Figure 6 summarizes the general impact areas for these strikes. Those hitting in the West Bank of Jordan presumably fell short of their intended targets in Israel proper.[128]

As noted in Section V, the director of Israel's Scud Recovery Unit indicated none of the missile warheads they recovered had chemical or biological warfare agent components. All had conventional warheads.[129]

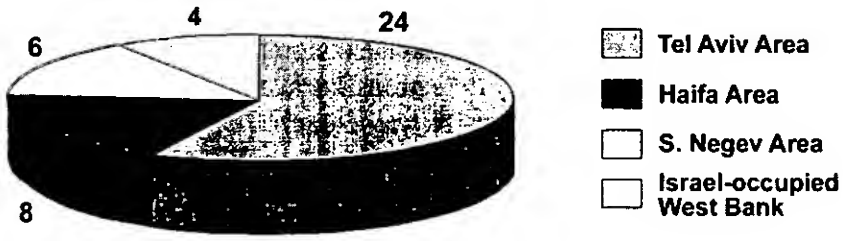

Figure 6. Where Scuds landed in or near Israel

The director of the Israeli Scud Recovery Unit also noted that when Patriots shot down a Scud, release of the residual rocket oxidizer (inhibited red fuming nitric acid) generated a cloud of yellow mist that caused burning sensations on exposed skin. Some who experienced Scud attacks incorrectly believed this yellow or orange cloud to be nerve agent.[130] See Section VII on Scud oxidizer incidents.

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[126] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 49; unidentified United States Army organization, "Scud Alert," February 21-22, 1991; Lead Sheet #18912, Interview of 354th Equipment Maintenance Squadron airman, September 10, 1998, p. 1.

[127] United States Central Command, "NBC Desk Log," February 25, 1991.

[128] Basic sources consulted in building this graph included the following cited extensively elsewhere is this paper: Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, p. 42-50; Watson, Bruce W., "Iraqi Scud Launches During the Gulf War," Appendix C, Military Lessons of the Gulf War, George Watson and Cyr Tsouras, London, Greenhill Books, 1991, p. 224-225; Defense Special Missile and Astronautics Center message, subject "Mideast Conflict: Iraqi SRBM Launch Summary through 26 February 1991," 271603Z Feb 91; Bermudez, Joseph S., Jr., "Iraqi Missile Operations During 'Desert Storm' – Update," *Jane's Soviet Intelligence Review*, May 1991, p. 225; "11th Air Defense Artillery Brigade, Chronology of Events," undated; United States Central Command, "NBC Desk Log," February 25, 1991.

[129] Special Assistant for Gulf War Illnesses, "Middle East Trip Provides Useful Information Exchange," January 27, 1998.

[130] Special Assistant for Gulf War Illnesses, "Middle East Trip Provides Useful Information Exchange," January 27, 1998.

log suggested that the additional impacts resulted from one Scud breaking up in flight.[117] Other reports noted that local eyewitnesses claimed a Scud broke up after another Scud missile or a Patriot hit it.[118] An official United States Air Force post-war assessment noted five Scud launches on the 14th.[119] Another Scud-tracking organization listed four launches on February 14th. Scuds struck no other target area on this date.[120] A nuclear-biological-chemical operations summary stated that one Scud in this attack had an airburst suspected of involving a chemical agent warhead. Units did both ground and aerial surveys. Reports did not indicate how the air survey was conducted, but part of the ground survey included use of a Fox chemical reconnaissance vehicle. The report noted that no contamination was found and that the air burst really involved the Scud breaking up in flight.[121]

Other reporting typifies the variety of accounts that surrounded Scud attacks. From reports that all of the impacts occurred in unoccupied desert areas (but there were casualties and damage in town) to accounts that witnesses saw three air bursts near the town with a warhead separating from one of the missiles (the only report noting three air bursts),[122] unclassified documentation clearly does not present a consistent picture regarding how many missiles were involved in this attack. Based on all available evidence, however, we assess that five separate Scuds struck in the area.

b. February 21st Attack on KKMC (Event 25 in Table 5)

Iraq launched this attack from the Baghdad area toward KKMC at about 9:00 PM.[123] Missile impact was expected about 12 miles north of the city.[124] However, the missile disintegrated prior to impact, and witnesses observed an air burst. All but two reports indicated Patriots defending the KKMC area did not attempt to engage the Scud.[125] Research revealed no indications of casualties or damage, but one source reported that debris fell in Trailer City, a temporary United

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[117] 3rd Armored Division intelligence staff, "Spot Report," February 14, 1991; XVIII Airborne Corps, Intelligence Spot Report Format, "Scud Update," February 14, 1991.

[118] XVIII Airborne Corps message Form, "Confirmation on Scuds," February 14, 1991; United States Army Component United States Central Command, "ARCENT Spot Report," February 14, 1991.

[119] Gulf War Air Power Survey, Volume I, Part I, Washington, DC: United States Government Printing Office, 1993, p. 245.

[120] Defense Special Missile and Astronautics Center message, subject "Mideast Conflict: Iraqi SRBM Launch Summary through 26 February 1991," 271603Z Feb 91.

[121] VII Corps, "Enclosure A to Appx 2 to Tab H to VII Corps DS AAR," undated; VII Corps, "Major Subordinate Command Historical Reports -- Task Force 8-43 ADA;" 2nd Armored Cavalry Regiment, "Operation Desert Storm AAR and Significant Events," March 6, 1991.

[122] VII Corps, "Major Subordinate Command Historical Reports -- Task Force 8-43 ADA."

[123] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 49; 11th Air Defense Artillery Brigade, "11th ADA Brigade S2's Chronology of Events," undated, p. 12.

[124] VII Corps, "Major Subordinate Command Historical Reports -- Task Force 8-43 ADA."

[125] United States Central Command, "SigOps Events," February 22, 1991; VII Corps, "Major Subordinate Command Historical Reports -- Task Force 8-43 ADA;" XVIII Airborne Corps, "Daily Staff Journal or Duty Officer's Log," February 21, 1991; unidentified United States Army organization, "Scud Alert," February 21-22, 1991; unidentified United States Army division intelligence staff, "Spot Report," February 21, 1991.

launched no Patriot missiles against these Scuds.[112] One Scud reportedly exploded in the southeast part of Hafir Al Batin collapsing the side of one house, stripping off the façade of another, and destroying an automobile maintenance workshop along with four or five cars.[113] Another Scud struck in a civilian district, but damage involved only broken windows. These missiles caused four minor injuries.[114]

Table 5. Scud attacks against KKMC/Hafir Al Batin area

Event #	Date (1991)	Time (Local)	# Scuds (Best est.)	Impact Area	Remarks
23	Feb 14	11:45 AM	Poss 5 (alt rpts 2, 3, 4)	Hafir Al Batin	First attack on this area and first in middle of day. Number of missiles unclear in evidence. Five impact areas reported, but most sources noted two Scuds that broke up. See Details on Selected Incidents below.
24	Feb 21	5:06 PM	2 (alt rpts 3)	KKMC	Seven Patriots fired, intercepting one or both Scuds (one Scud reportedly disintegrated on its own). No damage or casualties reported.[115]
25	Feb 21	9:00 PM	1	KKMC	Projected impact 12 miles north of city so Patriots did not engage. No casualties or damage. See Details on Selected Incidents below.
26	Feb 24	12:17 PM	1 (alt rpts 2)	KKMC	Patriot intercepted one missile. No casualties or damage reported. Second impact of debris recorded. Several sources incorrectly reported another Scud overflying.[116]

One log contained plots of five impacts for these attacks, but did not indicate which involved warheads (and hence separate missiles) and which might have resulted from debris. Three impacts happened close to the town and two at some distance to the south and to the east. The

[112] Unidentified United States Army intelligence staff, "Spot Report," February 14, 1991; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 49.

[113] United States Army Component United States Central Command, "ARCENT Spot Report," February 14, 1991; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 49.

[114] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 49.

[115] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 49; unidentified United States Army air defense element, "Daily Staff Journal or Duty Officer's Log," February 21, 1991; Defense Intelligence Agency, "NADA INTSUM 231-91," February 22, 1991; XVIII Airborne Corps personnel staff, "Daily Staff Journal or Duty Officer's Log," February 21, 1991; VII Corps, "Daily Log," February 21, 1991.

[116] Unidentified United States Army organization, "Scud Alert," February 24, 1991; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 50; unidentified United States Army air defense element, "Daily Staff Journal or Duty Officer's Log," February 24, 1991; XVIII Airborne Corps, "XVIII Airborne Corps Operation Desert Storm Chronology," February 1991.

apparently failed to disable the Scud warhead, which detonated damaging several buildings and slightly injuring 29 people.[108]

One report suggested Iraq launched a second Scud shortly after the first; however, the available evidence does not support this account.[109]

Two other sources recorded a successful intercept of the Scud. They stated that the engagement resulted in a mission kill (meaning a Patriot missile deflected the Scud from defended territory or the Scud warhead had significantly reduced effectiveness) and that the warhead hit in the desert east of Riyadh air base.[110] However, the damage and casualties in a populated area noted above attests that at least the warhead struck within the city. We found no evidence concerning chemical warfare agent testing for this event.

E. Scud Incidents in the KKMC and Hafir Al Batin Areas

1. Summary

Iraq targeted King Khalid Military City (KKMC) and the area around Hafir Al Batin with an estimated nine Scuds beginning in mid-February. See Table 5.

2. Details on Selected Incidents

a. February 14th Attack on Hafir Al Batin (Event 23 in Table 5)

On February 14, 1991, Iraq fired a barrage of Scud missiles in what was the first attack against the general KKMC/Hafir Al Batin area as well as the first attack against a military target in the middle of the day. The attack against Hafir Al Batin involved at least two Scuds and two different launch locations.[111] Patriot radars near KKMC tracked the Scuds, but because the missiles threatened an area outside the batteries' designated defense zone and range, the crews

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[106] 11th Air Defense Artillery Brigade, "11th ADA Brigade S2's Chronology of Events," undated, p. 11; Bermudez, Joseph S., Jr., "Iraqi Missile Operations During 'Desert Storm' – Update," *Jane's Soviet Intelligence Review*, May 1991, p. 225.

[107] Unidentified United States Central Command organization, "Scud Launch/Kill Summary," undated.

[108] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 48; VII Corps, "Jayhawk Daily News," February 4, 1991.

[109] Unidentified United States Army division air defense element "Spot Report Format," February 3, 1991.

[110] Watson, Bruce W., "Iraqi Scud Launches During the Gulf War," Appendix C, Military Lessons of the Gulf War, George Watson and Cyr Tsouras, London, Greenhill Books, 1991, p. 224; United States Central Command, "Daily Staff Journal Sig Ops Events," February 3, 1991.

[111] 11th Air Defense Artillery Brigade, "11th ADA Brigade S2's Chronology of Events," undated, p. 12; unidentified United States Army organization, "Iraq-Kuwait: Situation Update," February 14, 1991; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 49.

Dhahran combined "...because [Patriot] missiles went after [Patriot] missiles."[98] A log entry suggested that some Patriots fired on fragments from missile intercepts.[99] News media videotapes reportedly captured three ground explosions. One of the ground explosions near an office building blew out the back wall of one structure and produced a 10-foot crater. Twelve people had minor injuries.[100]

As in other Scud events, some logs reported a larger number of separate Scuds fired than we could confirm in our analysis of all available evidence.[101]

b. January 25th Attack on Riyadh (Event 15 in Table 4)

Late in the evening of January 25th, Iraq fired two Scud missiles toward Riyadh. Patriot batteries fired four missiles, reportedly intercepting both Scuds.[102] However, one of the Scud warheads completely demolished a six-story Saudi Department of Interior building in downtown Riyadh killing one Saudi and injuring 30 (most slightly). The warhead struck only a little over a mile south of the Ministry of Defense and Aviation building housing United States Central Command Headquarters.[103] At this building, communications technicians reported hearing a "loud boom" from above. They investigated the roof and found debris from the Scud. Nuclear-biological-chemical specialists who were called to the scene to test for chemical agents did not find any contamination and gave an "all clear."[104]

Although other sources reported three or five Scuds heading toward Riyadh,[105] available evidence points to only two Scuds.

c. February 3rd Attack on Riyadh (Event 18 in Table 4)

After almost five days of no strikes on the KTO, Iraq resumed Scud attacks with a single launch against Riyadh very early on February 3rd.[106] A Patriot battery fired two missiles[107] but

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[98] United States Army Component United States Central Command, ARCENT Spot Report, "CENTCOM Scud Update," January 21, 1991.

[99] VII Corps air defense element, "Daily Staff Journal or Duty Officer's Log," January 21, 1991.

[100] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 47.

[101] VII Corps, "Daily Log," September 3, 1991; unidentified United States Army division intelligence staff, "Journal Sheet," January 21, 1991; 11th Air Defense Artillery Brigade, "11th ADA Brigade S2's Chronology of Events," undated, p. 10,.

[102] Unidentified United States Army organization, "Scud Alert," January 25, 1991.

[103] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 48; Defense Special Missile and Astronautics Center message, subject: "Mideast Conflict: Iraqi SRBM Launch Summary through 26 February 1991," 271603Z Feb 91; unidentified United States Central Command organization, "Scud Launch/Kill Summary," undated; unidentified United States Army organization, "Scud Alert," January 25, 1991.

[104] United States Central Command, "Daily Staff Journal Sig Ops Events," January 25, 1991.

[105] VII Corps, "Major Subordinate Command Historical Reports -- Task Force 8-43 ADA;" VII Corps, "Daily Log;" January 25, 1991; 20th Engineer Brigade, "Daily Staff Journal or Duty Officer's Log," January 25, 1991.

Event #	Date (1991)	Time (Local)	# Scuds (Best est.)	Impact Area	Remarks (MULTIPLE PAGE TABLE)
19	Feb 8	1:54 AM	1 (alt rpts 2)	Riyadh	One of two Patriots fired reportedly intercepted this Scud north of city. However, warhead hit parking lot and detonated. No casualties or major damage. Patriots considered this a "mission kill"[93] (see glossary in Tab A).
20	Feb 11	10:20 PM	1 (alt rpts 2)	Riyadh	One of two Patriots intercepted, but warhead hit near swimming pool and building at Islamic University. It exploded causing significant damage. It broke many windows and slightly injured two people by flying glass. Considered Patriot "mission kill."[94]
21	Feb 24	4:32 AM	1	Riyadh	Two patriots fired and warhead kill claimed (it landed without exploding), but minor damage caused to Saudi school (no injuries).[95]
22	Feb 24	9:23 PM	1 (alt rpts 2)	Riyadh	Patriots fired two with one malfunction and command destruct. Other Patriot engaged Scud with "mission kill" reported. Scud broke up before or as result of intercept. No explosion from debris.[96]

2. Details on Selected Incidents

a. January 21st Attack on Riyadh (Event 12 in Table 4)

Shortly after midnight and within a few minutes of an attack against Dhahran (Event 2 in Table 3), Iraq launched four Scuds in the first attack on the Saudi capital of Riyadh. Patriot batteries in the area launched 26 missiles (eight at the first Scud and six at each that followed) recording kills against all targets.[97] One report noted the Patriots claimed 14 kills at Riyadh and

[93] United States Army Component United States Central Command operations staff United States Marine Component United States Central Command desk, "Daily Staff Journal or Duty Officer's Log," February 7, 1991; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 49; Bermudez, Joseph S., Jr., "Iraqi Missile Operations During 'Desert Storm' – Update," *Jane's Soviet Intelligence Review*, May 1991, p. 225; unidentified United States Central Command command post "JTF J2 Message Form/Journal Log," February 8, 1991; 2nd Armored Calvary Regiment, "Daily Staff Journal or Duty Officer's Log," February 8, 1991.

[94] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 49; unidentified United States Army organization, "Scud Alert," February 11, 1991; United States Central Command, "SigOps Events," January 25, 1991; unidentified United States Army intelligence staff, "Spot Report," February 11, 1991.

[95] Unidentified United States Army organization, "Scud Alert," February 24, 1991; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 50; United States Central Command, "Air Defense Operations," February 24, 1991.

[96] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 50; unidentified United States Army division air defense element, "Message Form/CTOC Journal Sheet," subject "Follow-up on SCUD Launch," February 25, 1991; VII Corps, "Daily Log," February 24, 1991; XVIII Airborne Corps, "XVIII Airborne Corps Operation Desert Storm Chronology," February 1991.

[97] Unidentified United States Central Command organization, "Scud Launch/Kill Summary," undated.

Event #	Date (1991)	Time (Local)	# Scuds (Best est.)	Impact Area	Remarks (MULTIPLE PAGE TABLE)
13	Jan 22	3:41 AM	3 (alt rpts 2-9)	Riyadh	Patriots engaged and possibly intercepted all three (30 Patriots fired). Debris noted south of town. TV coverage showed three ground explosions in area. Nearly intact Scud body (minus warhead and tail section) landed on a street. No casualties or damage.[89]
14	Jan 23	10:54 PM	2 (alt rpts 3-5)	Riyadh	Iraq fired five Scuds in a very short time – one at Israel and two each at Dhahran and Riyadh. In Riyadh, Patriots reportedly destroyed one or both. During this period, Patriots at KKMC fired at one false target and Patriots with VII Corps fired at two false targets.[90]
15	Jan 25	10:23 PM	2 (alt rpts 3-5)	Riyadh	Patriots intercepted with two missiles against each Scud. However, one Scud warhead demolished a six-story Saudi Department of Interior building killing one and injuring 30. See Details on Selected Incidents below.
16	Jan 26	10:46 PM	1 (alt rpts 2)	Riyadh	Patriots engaged Scud. Warhead exploded in empty field ¼ mile from United States Central Command Headquarters.[91]
17	Jan 28	8:55 PM	1 (alt rpts 3)	Riyadh	Patriots fired four missiles – one intercepted the Scud and the others engaged debris. Debris struck farm in suburbs with no significant damage.[92]
18	Feb 3	12:41 AM	1 (alt rpts 2)	Riyadh	Patriots fired two missiles, but Scud warhead detonated near apartment damaging several buildings and slightly injuring 29 people. See Details on Selected Incidents below.

[89] Unidentified United States Central Command organization, "Scud Launch/Kill Summary," undated; 82nd Airborne Division, "Daily Staff Journal or Duty Officer's Log," January 22, 1991; VII Corps, "Daily Log," January 22, 1991; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 48; VII Corps, "Daily Staff Journal or Duty Officer's Log," January 22, 1991; VII Corps, "Major Subordinate Command Historical Reports -- Task Force 8-43 ADA."

[90] United States Commander in Chief Central Command message, subject: "SITREP/USCINCCENT/168/Jan," 242115Z Jan 91, Section 5; unidentified United States Central Command organization, "Scud Launch/Kill Summary," undated; unidentified United States Army organization log, "Scud Launch Report," January 23, 1991; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 48; United States Central Command, "NBC Desk Log," January 23, 1991; unidentified United States Army air defense element, "Message Form/CTOC Journal Sheet," January 24, 1991.

[91] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 48; United States Army Component United States Central Command, "ARCENT Spot Report," January 26, 1991; 82nd Airborne Division, "Daily Staff Journal or Duty Officer's Log," January 26, 1991.

[92] Unidentified United States Central Command organization, "Scud Launch/Kill Summary," undated; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 48; unidentified United States Army organization, "Scud Alert," January 28, 1991; 3rd Armored Division intelligence staff, "Spot Report," January 28, 1991.

source, most of the injured suffered burns. Initially, some 40 soldiers were believed missing.[82] Most of the soldiers in the warehouse had just arrived and had not completely processed into their units. This, plus the presence of their personnel files and computer records in the same devastated warehouse, played havoc with the ability to account for people.[83] Helicopters eventually evacuated 70 to 100 soldiers to six hospitals including five Saudi facilities.[84] This single incident caused more combat casualties than any other in Operation Desert Storm.[85]

Some documentation includes alternative details to this horrific event. One message stated that this incident involved three confirmed launches (one against Dhahran, one against nearby King Fahd Airport and one against Qatar).[86] A press briefing attributed the lack of Patriot engagement to a combination of the warehouse location (housing) and debris trajectory from a disintegrating Scud.[87] The media quoted another senior officer as explaining that "because it [the Scud] had gone into a tumble ... it wasn't within the parameters of where it would be attacked by our missile defense system."[88]

D. Scud Incidents in the Riyadh Area

1. Summary

Investigators counted 18 Scuds fired against the area of Riyadh during Iraq's missile attacks. Table 4 and the details on selected incidents that follow address these attacks.

Table 4. Scud attacks against Riyadh area

Event #	Date (1991)	Time (Local)	# Scuds (Best est.)	Impact Area	Remarks (MULTIPLE PAGE TABLE)
12	Jan 21	12:42 AM	4 (alt rpts 6-17)	Riyadh	Scud attack on Riyadh coordinated with one against Dhahran (see Event 2 in Table 3). Patriot units in area fired 26 missiles and claimed all Scuds killed. See Details on Selected Incidents below.

[82] Watson, Bruce W., "Iraqi Scud Launches During the Gulf War," Appendix C, Military Lessons of the Gulf War, George Watson and Cyr Tsouras, London, Greenhill Books, 1991, p. 225; Office of the Chief of Naval Operations, "The United States Navy in 'Desert Shield/Desert Storm,'" May 15, 1991; unidentified United States Army operations staff, "Daily Staff Journal or Duty Officer's Log," February 25, 1991; United States Army Component United States Central Command, "ARCENT Spot Report," February 25, 1991.

[83] United States Army Component United States Central Command, "Mass Casualty – SCUD Attacks," United States Army Component United States Central Command Lessons Learned Worksheet, April 25, 1991.

[84] Unidentified United States Army organization, "Message Form," January 26, 1991.

[85] United States Army Component United States Central Command Support Command memorandum, "Written After Action Report, Desert Shield/Desert Storm," May 30, 1991.

[86] Unidentified United States Army operations staff, "Message Form/CTOC Journal Sheet," 252042C Feb 91.

[87] United States Central Command, "CINC's Press Briefing," February 27, 1991.

[88] "Scud Data Raise Questions About Barracks Destruction," *Wall Street Journal,* April 15, 1991, p. 16.

Scud.[76] The incoming missile broke up in flight over the harbor and hit in the water just off a large pier where six ships and two smaller craft were tied up. The missile's impact also was about 500 feet from ammunition storage on the pier.[77] Figure 4 displays a map of the harbor showing the impact location.

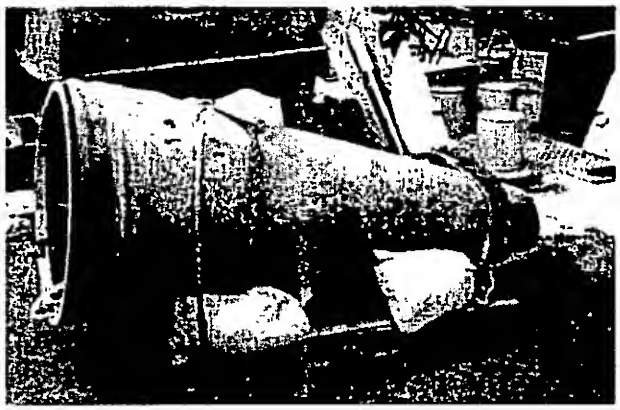

Figure 5. Recovered Scud warhead

One witness recalls hearing a loud explosion and seeing white-hot objects falling.[78] The Scud caused no casualties or damage, but it exuded a blue, green, and yellow substance and bubbled a strong-smelling gas for some time (probably inhibited red fuming nitric acid – see Section VII). United States Navy explosive ordnance disposal specialists eventually recovered the missile in parts using divers, flotation bags, and a crane. Test results performed on this Scud determined that it did not have a chemical or biological warhead.[79] Figure 5 shows the recovered high explosive warhead.[80]

d. February 25th Attack on Dhahran (Event 10 in Table 3)

Iraq launched one Scud toward Dhahran early in the evening of February 25th. One Patriot battery on Dhahran airfield was not operational and another nearby did not track the Scud, apparently because of a software problem.[81] The Scud broke up on reentry showering a United States housing compound with debris, and the warhead hit a warehouse serving as a United States barracks in Aujan compound in the Dhahran suburb of Al Khobar. The strong explosion and resulting fire killed 28 United States soldiers from the 475th Quartermaster Group (a United States Army Reserve unit) and injured 100, about half of them seriously. According to one

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March 1993, p. 49; Bermudez, Joseph S., Jr., "Iraqi Missile Operations During 'Desert Storm' – Update," *Jane's Soviet Intelligence Review*, May 1991, p. 225.

[76] Center for Naval Analysis, "Case Study of a Tactical Ballistic Missile (TBM) Attack: Al Jubayl, Saudi Arabia, 15-16 February 1991 (U)," August 1996 (S).

[77] Marine Aviation Logistics Squadron 16, "Command Chronology 1-28 Feb 91," Section II, March 1, 1991; Center for Naval Analysis, "Case Study of a Tactical Ballistic Missile (TBM) Attack: Al Jubayl, Saudi Arabia, 15-16 February 1991 (U)," August 1996 (S); and Special Assistant for Gulf War Illnesses, "Al Jubayl, Saudi Arabia" (Case Narrative), August 13, 1997, web site www.gulflink.osd.mil/aljubayl/.

[78] Lead Sheet #1410, Interview of United States Coast Guard watch stander, February 24, 1997, p. 2.

[79] Lead Sheet #1232, Interview of United States Navy explosive ordnance disposal specialist, January 8, 1991, p. 2; Lead Sheet #16642, Interview of 390th Transportation Unit soldier, May 19, 1998, p. 1; Lead Sheet #10922, Interview of 567th Transportation Company soldier, October 8, 1997, p. 2,3.

[80] United States Coast Guard Port Security Unit 301, "Port Security Unit-301, Al-Jubayl Saudi Arabia 1990-91," undated.

[81] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 50; unidentified United States Army air defense element message form, "Scud Launch," 252210C Feb 91.

b. January 22nd Attack on Dhahran (Event 4 in Table 3)

Shortly after 7:00 AM on January 22nd, Iraq fired three Scuds toward Dhahran. The first two flew outside of the Patriots' defended area with at least one landing in the desert about 50 miles west of town. The other reportedly went down in Gulf waters north of Qatar. Most unclassified sources credit Patriots with intercepting the third Scud.[71] Debris reportedly struck on a Dhahran Air Base runway just as an aircraft took off to the south; but the aircraft apparently escaped damage.[72] Most pieces of debris were described as small (less than 3 inches), but something falling out of the sky caused a crater 23 feet in diameter and 4 feet deep on the air base. All but one field test indicated no presence of chemical warfare agent. In that one positive chemical warfare agent test, a chemical agent monitor registered a very low concentration on the nerve agent scale. Subsequent testing at that location proved negative.[73] A Fox chemical reconnaissance vehicle (see glossary at Tab A) took samples from the crater area for additional testing, but we found no specific results of any Fox tests.

Alternative reporting included a fourth Scud that appeared in some chronologies at this time as a target for two Patriot launches. However, this track represented a false target (radar interference – see Section VI.B). One summary suggested that Patriot units fired two missiles at each of three Scuds.[74]

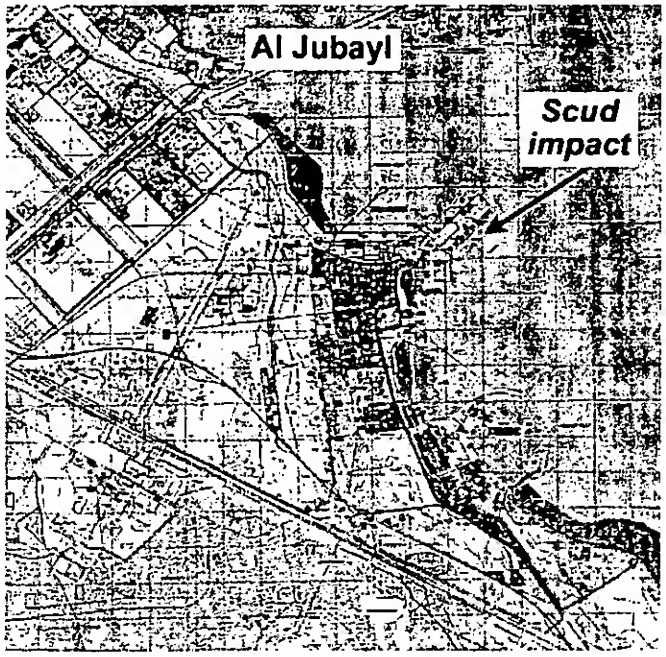

Figure 4. Map of Al Jubayl harbor Scud impact location

c. February 16th Attack on Al Jubayl (Event 7 in Table 3)

Iraq fired a single Scud at the port city of Al Jubayl early on February 16th.[75] The Patriot battery positioned to defend Al Jubayl was undergoing maintenance at the time and could not engage the

[71] Unidentified United States Central Command organization, "Scud Launch/Kill Summary," undated; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 48; Bermudez, Joseph S., Jr., "Iraqi Missile Operations During 'Desert Storm' – Update," *Jane's Soviet Intelligence Review*, May 1991, p. 225; United States Central Command, "SigOps Events," January 22, 1991.

[72] As documented by 3rd Armored Division intelligence staff, "Spot Report," January 22, 1991.

[73] 1st Tactical Fighter Wing (Provisional), "Log of Events."

[74] Unidentified United States Central Command organization, "Scud Launch/Kill Summary," undated; Defense Special Missile and Astronautics Center message, subject: "Mideast Conflict: Iraqi SRBM Launch Summary through 26 February 1991," 271603Z Feb 91.

[75] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA,

Event #	Date (1991)	Time (Local)	# Scuds (Best est.)	Impact Area	Remarks (MULTIPLE PAGE TABLE)
10	Feb 25	8:32 PM	1 (alt rpts 3)	Dhahran	Of two Patriot batteries in range, one was non-operational and other did not detect Scud because of software problem. Warhead hit United States barracks killing 28 and injuring over 100. See Details on Selected Incidents below.
11	Feb 26	1:26 AM	1 (alt rpts 3)	Qatar	Scud overflew Dhahran headed for Qatar. No Patriot engaged because it was out of defense zone. Scud fell into Gulf 40 miles off Doha, Qatar.[65]

2. Details on Selected Incidents

a. January 20th Attack on Dhahran (Event 1 in Table 3)

Shortly before 10 PM on January 20th, Iraq fired the first two Scuds at the Dhahran area.[66] One report noted that Patriot units fired five missiles at three (rather than the actual two) Scuds and that M8 chemical agent alarms went off, but subsequent tests proved negative.[67] A separate United States Air Force unit at Dhahran logged an entry at 9:50 PM noting multiple explosions. Checks revealed that none of that unit's chemical agent detectors had alarmed. A later entry reported a possible impact near a barracks and the United States Army Component United States Central Command headquarters as well as near a Saudi police camp and the port area. Subsequent investigation turned up no building damage, casualties, or unexploded ordnance.[68] A witness to the January 20th attack remembered that a Patriot battery took out the Scuds near a pier in Dhahran and that everybody went to MOPP Level 4 (full chemical protection – see glossary at Tab A) for about six or seven hours while tests and assessments were made. He did not know the test results, but an "all clear" was sounded permitting a termination of the chemical alert.[69] A chemical company soldier remembered witnessing repeated M8A1 chemical agent alarms and positive M256 chemical detection kit tests the first night of Scud attacks in the Dhahran area and recalls remaining in MOPP Level 4 for seven hours. He believed no one had chemical agent symptoms.[70]

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[65] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 50; XVIII Airborne Corps, "XVIII Airborne Corps Operation Desert Storm Chronology," February 1991; unidentified United States Army air defense element message form, February 25, 1991.

[66] Watson, Bruce W., "Iraqi Scud Launches During the Gulf War," Appendix C, Military Lessons of the Gulf War, George Watson and Cyr Tsouras, London, Greenhill Books, 1991, p. 224 225; unidentified United States Central Command organization, "Scud Launch/Kill Summary," undated; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 47.

[67] United States Central Command, "G-3 Spot Report," January 20, 1991.

[68] The Air Force element did not have a M8A1 Chemical Agent Alarm go off and checked using Chemical Agent Monitor (CAM) and M256A1 Chemical Agent Detection Kit. 1st Tactical Fighter Wing (Provisional), "Log of Events."

[69] Lead Sheet #15828, Interview of 3rd Armored Division soldier, April 9, 1998, p. 1.

[70] Lead Sheet #16866, Interview of 318th Chemical Company soldier, May 28, 1998, p. 2.

Event #	Date (1991)	Time (Local)	# Scuds (Best est.)	Impact Area	Remarks (MULTIPLE PAGE TABLE)
4	Jan 22	7:10 AM	3 (alt rpts 4)	Dhahran	Scuds one and two were not engaged and hit outside of town. Scud three was intercepted by Patriots and landed off Qatar. Debris hit Dhahran area. Most chemical warfare agent tests were negative. See Details on Selected Incidents below.
5	Jan 23	10:54 PM	2 (alt rpts 3-5)	Dhahran	Iraq rapidly fired five Scuds – one at Israel and two each at Dhahran and Riyadh. Of the two Scuds fired at Dhahran, Patriots intercepted at least one. Debris fell within and just outside United States occupied base.[61]
6	Jan 26	3:28 AM	1 (alt rpts 2)	Dhahran	Successful Patriot engagement reported. Debris hit Dhahran International Airport.[62]
7	Feb 16	2:01 AM	1	Al Jubayl	Patriot down for maintenance – no engagement. Scud broke up over harbor and hit the water near ammunition pier. See Details on Selected Incidents below.
8	Feb 22	2:31 AM	3 (alt rpts 1-2)	Bahrain	First time targeted. Patriot battery on Bahrain engaged one Scud and debris was found. Other two Scuds were out of defended area.[63]
9	Feb 23	4:59 AM	2 (alt rpts 1, 4)	Dhahran	Scud one had non-threatening trajectory, and Patriots did not engage it. It landed 12 miles north of King Fahd International Airport. Scud two broke up in flight.[64]

March 1993, p. 47; 11th Air Defense Artillery Brigade, "11th Air Defense Artillery Brigade S2's Chronology of Events," p. 10; 82nd Airborne Division, "Daily Staff Journal or Duty Officer's Log," January 21, 1991.

[61] Unidentified United States Army corps daily summary for January 23, 1991; 1st Tactical Fighter Wing (Provisional), "Log of Events;" unidentified United States Central Command organization, "Scud Launch/Kill Summary," undated; VII Corps, "Daily Log," January 22, 1991; Lead Sheet #21097, Interview of B Company, 702nd Transportation Battalion soldier, January 14, 1999; United States commander in chief Central Command message, subject: "SITREP/USCINCCENT/168/Jan," 242115Z Jan 91; unidentified United States Army operations staff air defense element message, subject "Scud Launch," January 23, 1991.

[62] XVIII Airborne Corps, "XVIII Airborne Corps Operation Desert Storm Chronology," January 1991; United States Army Component United States Central Command, "ARCENT Spot Report," January 26, 1991; unidentified United States Central Command organization, "Scud Launch/Kill Summary," undated; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 48; Bermudez, Joseph S., Jr., "Iraqi Missile Operations During 'Desert Storm' – Update," *Jane's Soviet Intelligence Review*, May 1991, p. 225; United States Central Command, "NBC Desk Log," January 26, 1991; 1st Explosive Ordnance Disposal Group, "1st EOD Group Daily Journal," January 25, 1991.

[63] XVIII Airborne Corps, "XVII Airborne Corps Operation Desert Storm Chronology," February, 1991; VII Corps, "Major Subordinate Command Historical Reports -- Task Force 8-43 ADA."

[64] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 50; Bermudez, Joseph S., Jr., "Iraqi Missile Operations During 'Desert Storm' – Update," *Jane's Soviet Intelligence Review*, May 1991, p. 225; Office of the Chief of Naval Operations, "The United States Navy in 'Desert Shield'/'Desert Storm," May 15, 1991; VII Corps, "Major Subordinate Command Historical Reports -- Task Force 8-43 ADA;" VII Corps, "Daily Log, September 3, 1991.

the large but now significantly lighter missile body could decelerate enough from air resistance to survive impact almost intact, as several did.[58]

C. Scud Incidents in the Eastern KTO

Below we address Scud attacks in the Eastern KTO. In this section and those that follow, we summarize the nature of attacks in table entries, including the best available information on the number of attacking missiles. We also note alternative missile numbers we determined were inaccurate but that appeared somewhere in operational reporting (alternative reporting or "alt rpts" numbers in the fourth column). We follow the tables with more detailed accounts of a few incidents chosen because of potential veteran interest or operational significance. Often, many unit logs, chronologies, and summaries recorded the same Scud attack. In such cases we cite only representative and substantive samples for practical reasons. However, we reviewed all cited references as different documents often contained additional data that could provide a more complete picture of the incidents.

1. Summary

Evidence indicates that Iraq fired 19 Scuds against the areas of Dhahran, Al Jubayl, Bahrain, and Qatar. Table 3 summarizes the details and describes each event.

Table 3. Scud attacks against Eastern KTO

Event #	Date (1991)	Time (Local)	# Scuds (Best est.)	Impact Area	Remarks (MULTIPLE PAGE TABLE)
1	Jan 20	9:43 PM	2 (alt rpts 3)	Dhahran	Some sources reported three Scuds. Chemical alarms went off, tests were negative. Patriots claimed 2 kills. MOPP Level 4 (see Tab A) was in effect for six to seven hours. Debris and two impacts found. See Details on Selected Incidents below.
2	Jan 21	12:29 AM	2 (alt rpts 3)	Dhahran	Patriots claimed one kill, let other hit water. Debris hit runway at Dhahran International Airport, outside an aircraft bunker, and other areas.[59]
3	Jan 21	10:18 PM	1 (alt rpts 2)	Al Jubayl	No Patriot engagement.[60] Target may have been Dhahran.

[58] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 48.

[59] Unidentified United States Central Command organization, "Scud Launch/Kill Summary," undated; 82nd Airborne Division, "Daily Staff Journal or Duty Officer's Log," January 21, 1991; unidentified United States Army division air defense message form, 202157Z Jan 91; XVIII Airborne Corps, "XVIII Airborne Corps Operation Desert Storm Chronology," January 1991; Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 47; Bermudez, Joseph S., Jr., "Iraqi Missile Operations During 'Desert Storm' – Update," *Jane's Soviet Intelligence Review*, May 1991, p. 225; Lead Sheet #13099, Interview of Marine aviation technician supervisor, December 19, 1997.

[60] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA,

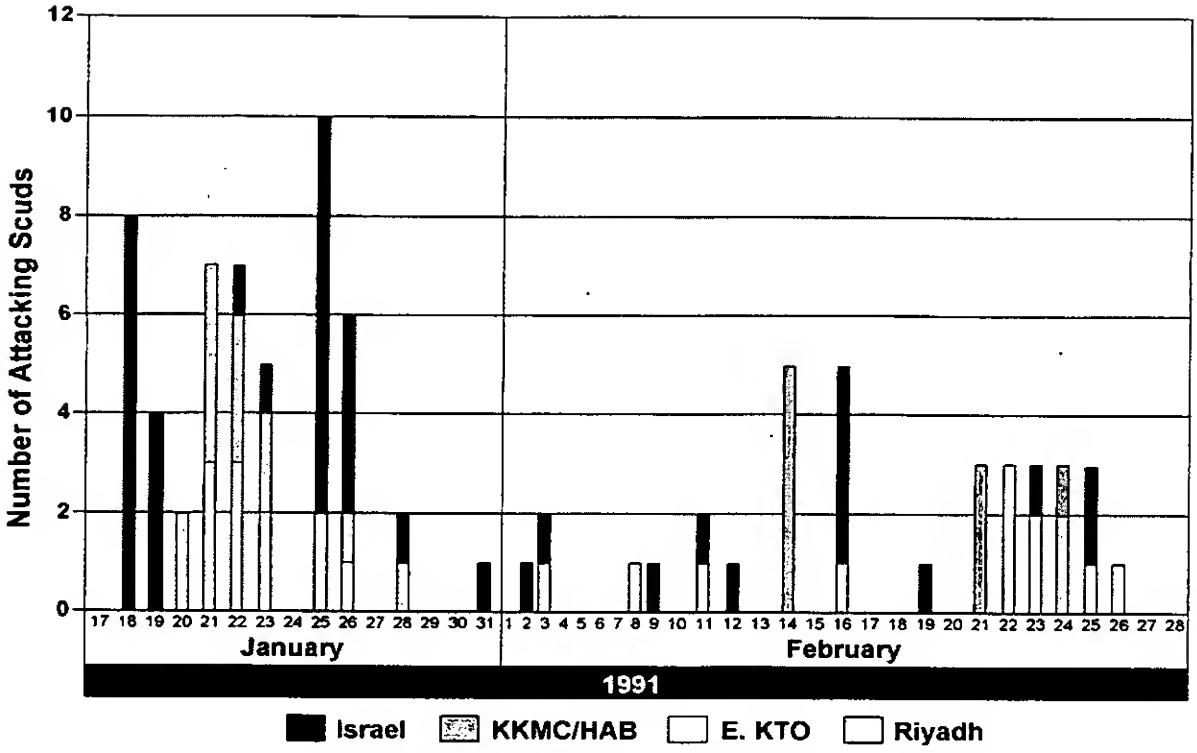

Figure 3. Scud attacks by target area

During the war, some intelligence estimates concluded that Iraq fired Al Abbas missiles with an even greater estimated range than the Al Hussein. Authorities later determined that Iraq fired only the Al Hussein extended range missile except for five attacks with the Al Hijarah variant.[56]

The KKMC/Hafir Al Batin area did not get targeted until the later stages of the Scud attacks. At the end of the war, Iraq fired several Scuds toward Bahrain and Qatar in the eastern KTO (See the regional summaries in Sections C and E below.)

Because many Scuds broke up as they reentered the denser atmosphere, and Patriots intercepted others, some observers might believe a single missile attack included more missiles than was the case. Also, the kinetic energy of heavy debris striking the ground at about 3,600 miles per hour (one mile per second) could cause a significant crater.[57] Both the heavy warhead and engine sections sometimes separated from either end of the missile body on reentry. In these instances,

[56] Defense Intelligence Agency, Defense Security Assessment 181A-91, "Iraq-Kuwait: Situation Update," February 23, 1991; Central Intelligence Agency, "Chronology of Iraqi CW Development;" Jane's Information Group, "Al Hussein," *Jane's Strategic Weapon Systems 1995-96*, September 16, 1996.

[57] Postol, Theodore A., "Lessons of the Gulf War Experience with Patriot," *International Security*, winter 1991/92, p. 133.

Table 2. Number of missiles fired by source

Source	Atk'd KTO	Atk'd Israel	Total Attacks	Remarks
Special Assistant for Gulf War Illnesses[48]	46	42	88	Case Narrative – "Al Jubayl, Saudi Arabia"
Department of Defense Report to Congress[49]	N/A	N/A	88	Published in April 1992.
Defense Special Missile and Astronautics Center[50]	45	40	85	Disseminated on February 27, 1991, just before the ceasefire.
Iraq, as reported to United Nations Special Commission[51]	50	43	93	Further details are not in the public domain, but Iraq's launch information agreed well with other sources (with a few exceptions).
United States Space Command[52]	N/A	N/A	97	Based on Defense Support Program infrared satellite data on launches (rather than impacts in target areas).
Center for International Studies[53]	42	39	81	Plus 5-8 that failed shortly after launch.
Military Lessons of the Gulf War[54]	46	40	86	A book published after the war in 1991.
Jane's Soviet Intelligence Review [55]	46	40	86	Plus "five missiles believed to have broken up immediately after launch and did not reach Saudi Arabia or Israel."

[48] Special Assistant for Gulf War Illnesses, "Al Jubayl, Saudi Arabia," (Case Narrative) , web site www.gulflink.osd.mil/al_jubayl/, August 13, 1997, p. 2.
[49] Department of Defense Final Report to Congress, "Conduct of the Persian Gulf War," April 1992, p. 165.
[50] Defense Special Missile and Astronautics Center message, subject "Mideast Conflict: Iraqi SRBM Launch Summary through 26 February 1991," 271603Z Feb 91.
[51] United Nations Special Commission, "UNSCOM's Comprehensive Review," Annex A, Status of the Material Balances in the Missile area, and cover letter, January 25, 1999, web site: www.un.org (as of March 10, 2000).
[52] Memorandum from Air Force Space Command vice commander to Headquarters, United States Space Command, Subject: "Declassification/Security Review Request from OSD," December 9, 1998.
[53] Lewis, George N., Steve Fetter, and Lisbeth Gronlund, "Casualties and Damage from Scud Attacks in the 1991 Gulf War," Appendix, Center for International Studies, Massachusetts Institute of Technology, Cambridge, MA, March 1993, p. 42.
[54] Watson, Bruce W., "Iraqi Scud Launches During the Gulf War," Appendix C, Military Lessons of the Gulf War, George Watson and Cyr Tsouras, London, Greenhill Books, 1991, p. 225-226.
[55] Bermudez, Joseph S., Jr., "Iraqi Missile Operations During 'Desert Storm' – Update," *Jane's Soviet Intelligence Review*, May 1991, p. 225.

region of KKMC and Hafir Al Batin, and finally Israel. We summarize in tables the Scud strikes against each KTO region and follow the tables with a few more detailed accounts of the most significant incidents.

B. Total Scud Firing Incidents

At one of our veterans' outreach programs in 1998, a veteran questioned the number of Scud missiles fired against Coalition forces during the Gulf War. He based his opinions on an internal working document produced by the Armed Forces Center for Unit Records Research (CURR) and provided by that Department of Defense organization to some veterans. The listing had 179 incident entries totaling 344 missiles. A junior officer of the Center had compiled a list of Scud launch information from hundreds of operational reports, many with inconsistent data. Not knowing which accounts were correct, this officer included all versions of what happened. CURR designed the list to serve as a reference for responding to veterans' communications regarding Scud incidents at particular times. Our research and analysis confirmed that Iraq fired 46 Scuds into the KTO. The rest of the entries in the CURR list involve duplicate reporting or other incorrect information. We have included the CURR compilation and our analysis of it in Tab D. The operational documents that CURR used as sources for their summary we used in preparing this information paper. Many of these documents were not previously available.

After the Gulf War, various authors and government agencies published assessments of Iraq's Scud attacks including the numbers of missiles fired at Coalition forces and Israel. Pieced together from differing data sets, the totals varied generally within a narrow range. Table 2 summarizes the data from selected authors and organizations. The United States Space Command's count of 97 launches includes nine more than the 88 missiles our investigation determined struck Coalition countries and in or near Israel. Some of the sources cited in Table 2 noted several early in-flight failures that could explain this difference. In reassessing unclassified or declassified material on individual attacks, we can now account for the 46 Scuds that attacked the KTO but only 41 of the 42 Scuds that struck in or near Israel (for a total of 87). However, based on all available information, including classified documents, we are confident that a total of 88 missiles struck in or near the KTO and Israel. In the summaries that follow we break out the 87 firing incidents covered in unclassified or declassified documents by general area attacked (the eastern KTO, Riyadh, KKMC/Hafir Al Batin, and Israel). These incidents are summarized in Figure 3.[47] After an initial period of intense daily attacks, the number of missiles launched against the Coalition and Israel per day fell off substantially.

[47] Graph based on summaries for each geographic area in section V.

cases, we could not identify the originating military organization, but all such evidence came from archives of official documents that the services reviewed for use in this paper.

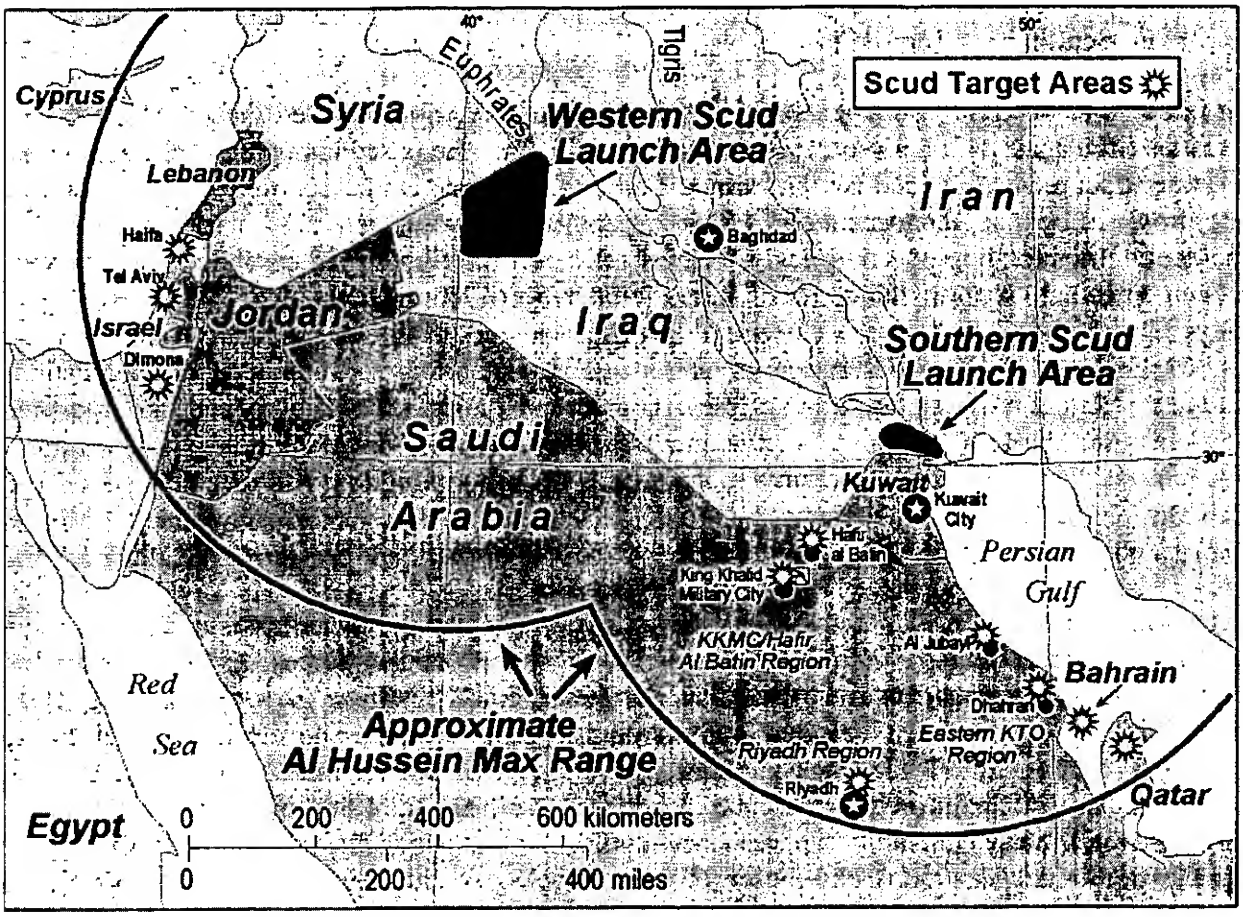

Figure 2. Scud launch areas, target regions, and Al Hussein range

The brief summaries that follow integrate what we know regarding Scuds fired at targets in the KTO and against Israel. The map in Figure 2 plots generalized launch locations in Iraq, impact areas in the KTO and Israel, and approximate maximum range of Scuds from the launch areas.[45]

We have converted all times to local date and time in the KTO.[46]

In the rest of this section we first discuss the total number of Scud missiles fired at Coalition forces and Israel during the Gulf War. Available counts vary. We follow this with separate coverage of the Scud attacks in four geographic regions: the eastern KTO, the Riyadh area, the

[45] Scud firing areas based on Gulf War Air Power Survey, Volume II, Part II, Washington, DC: United States Government Printing Office, 1993, p. 400.

[46] Readers are cautioned to note the difference in the time zones used in cited references, hyperlinked in the online version, and to add three hours to "Z times" to track with the convention used in this paper. Also note that such conversions in the middle of the night (when many of the Scuds flew) can change the date as well as the time. For example, 2300Z (11:00 PM in London) on February 4th equals 0200C (2:00 AM in the KTO) on February 5th.

would counterattack with nuclear weapons. According to Iraq, Israeli officials sent a similar message.[42]

The Central Intelligence Agency (CIA) assessed that Iraq did not use chemical or biological weapons against Coalition forces in the Gulf War.[43] For example, Near East South Asia (NESA), a CIA office focused on the Middle East and other areas, thoroughly searched their files regarding potential use of chemical warfare (CW) of biological warfare (BW) agents by Iraq during the Gulf War. They summarized the results as follows: 1) They found no evidence that Iraq's leaders ordered chemical or biological warfare agent use during the Gulf War and no conclusive evidence that Iraq's forces employed those weapons; 2) Iraq had some Scud missile warheads loaded with CW and BW agents, and Iraq planned to retaliate with CW and BW weapons for a nuclear attack on Baghdad; and 3) Husayn Kamil (Saddam Hussein's brother-in-law and former chief of Iraq's nuclear-biological-chemical weapons development who defected to the west) stated in August 1995 that Iraq's officials believed that the United States would respond with tactical nuclear weapons if Iraq used chemical or biological weapons against the Coalition.[44] This summary suggests that Iraq did not employ CW or BW weapons against Coalition forces.

We have assembled in Tab C excerpts from operational reports regarding chemical agent testing and any symptoms (or lack thereof) for the Scud incidents in the Kuwait theater of operations discussed in Section V below. Reporting on this issue demonstrates that Iraq did not arm Scuds launched against Coalition forces with chemical warheads.

V. IRAQ'S USE OF SCUDS DURING OPERATION DESERT STORM

A. Introduction

Support for this Information Paper came from hundreds of pages of operational and open source evidence, allowing investigators to piece together lists of Iraq's Scud firings (presented below by general target area). Source documents sometimes contained inconsistent information. Even official logs and chronologies frequently recorded disparate detail and third-hand accounts. While a large volume of contemporary 1991 operational reporting has been declassified or released, some of the most reliable sources of information on Scud firings contain sensitive details and remain classified. Investigators considered all available information in constructing summaries for each attack. For completeness, however, our summaries below cite reports with alternative information on numbers of Scuds in an attack, Patriot defensive reactions, ground damage, and other details. For some operational logs and chronologies we uncovered only individual pages detached at some point and set aside because they touched on Scuds. In some

[42] Centre for Defence and International Security Studies, "Devil's Brews Briefings: Iraq," web site: www.cdiss.org (as of September 9, 1997); Central Intelligence Agency, "Why WMD were Withheld," March 1991.
[43] Central Intelligence Agency, "CIA Report on Intelligence Related to Gulf War Illnesses," August 2, 1996.
[44] Central Intelligence Agency, "Review of NESA Files," February 21, 1996; Central Intelligence Agency, "Why WMD were Withheld," March 1991.

Baghdad off balance, and Saddam and his generals may not have wanted to risk the expected massive retaliation for a minimal tactical advantage.[36]

C. Post-War Findings

A declassified DIA document reported that a thorough analysis of each Scud impact point in at least the King Khalid Military City (KKMC) area uncovered no evidence of chemical warfare agents or their decomposition products.[37] We did not find any indication of verified detection of chemical warfare agents in any other Scud impact areas, including Israel where officials confirmed all Scud warheads recovered were conventional.[38]

In accepting United Nations Security Council Resolution 687 of April 3, 1991, Iraq agreed to a cease-fire, intrusive inspections, and elimination of their weapons of mass destruction and related materiel including Scuds. To perform the inspections and monitor Iraq's compliance with the agreement, the United Nations created the United Nations Special Commission (UNSCOM).[39]

After the Gulf War, publicly-released UNSCOM information, as well as the United States intelligence community's independent information collection and analysis, provided insight regarding Iraq's ability to field Scuds fitted with chemical and biological warfare agent warheads. From such sources, we gained perspective on what the Coalition might have faced had Iraq possessed and used workable Scuds with such warheads. UNSCOM verified that Iraq produced 50 chemical and 25 biological Scud warheads that could have been filled for field operations. Iraq also produced five warheads specifically designed for trials of chemical warfare agents. Of the 50 chemical warfare agent warheads, 16 were filled with the nerve agent sarin and 34 were filled with binary components (chemicals that mix and produce sarin nerve agent) or the persistent nerve agent VX. UNSCOM did not identify the biological agents.[40]

In 1995, Iraq admitted to UNSCOM inspectors that it had produced the biological warfare agents anthrax, botulinum toxin, and aflatoxin.[41] Inspectors found that Iraq had launched a crash program in December 1990 to field weapons with BW agents to include artillery shells and some Al Hussein Scuds. Iraq claimed they never used such weapons because the United States sent them a message implying that if Iraq used chemical or biological weapons, the United States

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[36] Tactical Air Command, "CENTAF-Rear DISUM 184," 062300Z Mar 91.
[37] Defense Intelligence Agency message, subject "IIR 6 284 0008 94/Detection of Chemical Agents By Czechoslovak Unit during Desert Storm, Part III," 141325Z Oct 93.
[38] Special Assistant for Gulf War Illnesses, "Middle East Trip Provides Useful Information Exchange," January 27, 1998.
[39] United Nations Special Commission, "UNSCOM's Comprehensive Review," Annex A, Status of the Material Balances in the Missile Area, and cover letter, January 25, 1999, web site: www.un.org (as of March 10, 2000).
[40] Federation of American Scientists, "UNSCOM and Iraqi Missiles," web site: www.fas.org (as of May 13, 1999); Defense Intelligence Agency electronic mail, subject: "Preliminary Response on Information Paper Entitled 'Iraq's SCUD Ballistic Missiles (U),'" April 17, 2000 (S).
[41] Department of State, "Iraq Weapons of Mass Destruction Programs," United States Government white paper, February 13, 1998.

However, the expected chemical or biological attacks did not materialize. Even before the Gulf War ended, media reporting indicated Iraq had used no such weapons aboard Scuds. As one newspaper article noted, "Speculation that Iraq also would fit chemical warheads atop longer-range Al-Hussein and Al-Abbas missiles have [*sic*] not been borne out by the 67 firings so far of these missiles on civilian and military targets in Israel and Saudi Arabia. This fact has caused some officials to conclude that Iraq still lacks the capability of placing chemical warheads on the longer-range Scuds."[32]

Intelligence suggested one possible reason no chemical or biological warfare attacks had occurred. The CIA reported in January 1991 that, while Iraq had chemical warheads for Scud missiles, it had not yet mastered the fuse technology and trigger mechanism to detonate the warhead. The same report stated that Iraq's missile officials were considering having Scud missiles deliver chemical or biological weapons, counting on Patriot missiles to intercept the Scuds, thus dispersing the agent and contaminating an estimated 60 square kilometers (23 square miles).[33] Such a concept suggested that Iraq knew that their own Scud contact fusing could not do a good job, although an area would still be contaminated. As a United States government assessment indicated at the time, analysts did not expect a Patriot intercept to increase dissemination of agent, and it might greatly reduce such dissemination.[34]

The *Armed Forces Journal International* magazine also reflected upon the technical challenges involved in arming Scuds with chemical warfare payloads:

> Why have not Iraqi Scud chemical warheads appeared? Though there are reliable reports that the Iraqis have tested such warheads, technological challenges in the design of such warheads are more formidable than most reports have suggested.... The main hurdle in chemical warhead design is the missile's high terminal speed, nearly one mile per second. For a chemical warhead to function properly, it must dispense the liquid agent into an aerosol cloud a fraction of a second before impact. This is accomplished using a proximity fuse in the nose of the warhead detonating a burster charge in its base. The fuse must withstand the substantial heat build-up, shock, and vibration of descent. The burster charge must be sufficient to breach the warhead casing without destroying the small load of toxic liquid. If either device fails, the warhead plunges into the ground and the chemical agent is largely destroyed or absorbed.[35]

The United States Air Force's Tactical Air Command speculated in early March 1991 that

> Iraq well may have refrained from employing chemical agents for political and tactical reasons including inadequate targeting and intelligence and adverse weather. In addition, the tempo and magnitude of the coalition campaign kept

[32] Smith, R. Jeffrey, "Iraq's Chemical Weapons Still a Threat to Ground Troops, U.S. Says," *The Washington Post*, February 19, 1991, p. 7.
[33] Central Intelligence Agency, "Iraqi Special Weapons Capabilities," January 1991.
[34] Defense Intelligence Agency, "Effects of Patriot Interception on SCUD Warhead," January 23, 1991.
[35] "No Chem Scuds?" *Armed Forces Journal International*, March 1991, p. 23.

Another CIA document stated:

> If Saddam concluded his personal position was becoming hopeless, this could convince him to use biological weapons to shock the Coalition into a cease-fire. In such a situation, the use of anthrax against a coalition military installation or a major Saudi oil facility might seem an attractive option.... Iraq is almost certain to use chemical weapons tactically to avoid serious battlefield defeats.[23]

B. Information During The War

After Iraq began its Scud attacks, Coalition forces saw reports suggesting the possibility of imminent attacks by Iraq with chemically or biologically armed Scuds. The first Scud attack on Israel occurred on January 18, 1991, the day after the Coalition began offensive air operations. An 82nd Airborne Division log sheet noted at 5:32 AM on January 18th that "Israelis have informed the United States that at least some of the missiles that impacted were chemical rds [rounds]."[24] We could not determine who initiated this report, and shortly after 6:00 AM a retraction was transmitted.[25] Israeli officials confirmed to the Special Assistant for Gulf War Illnesses that none of the Scuds that attacked Israel carried chemical or biological agent warheads.[26]

As the Coalition air campaign proceeded, a VII Corps log included an entry at 8:00 PM on January 20th noting that "a source of unknown reliability" stated that Saddam had ordered a chemical/biological attack for the following day.[27] The XVIII Airborne Corps advised the 82nd Airborne Division intelligence staff several hours later that a chemical (or biological) attack would most likely come by surface-to-surface missiles and estimated the likelihood of such an attack at 50 percent.[28]

On January 27, 1991, another report stated that Saddam Hussein had ordered the beginning of chemical attacks.[29] The CIA noted that Iraq's forces "would be 'virtually certain' to use chemical weapons if they were pushed back by an Allied offensive."[30] As the Coalition ground campaign began, the DIA assessed that "Baghdad may be tempted to launch non-conventional [i.e., chemical or biological warfare agent] attacks with whatever warheads are available."[31]

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[23] Central Intelligence Agency, "Iraq as a Military Adversary," November 1990.
[24] 82nd Airborne Division, "Daily Staff Journal or Duty Officer's Log," January 18, 1991.
[25] VII Corps, "Defense of the Wadi Al Batin," p. 91.
[26] Special Assistant for Gulf War Illnesses, "Middle East Trip Provides Useful Information Exchange," January 27, 1998.
[27] VII Corps, "Daily Staff Journal or Duty Officer's Log," January 20, 1991.
[28] 82nd Airborne Division intelligence staff, "Message Form/CTOC Journal Sheet," January 21, 1991.
[29] Defense Intelligence Agency, Defense Security Assessment 91A-91, "Iraq-Kuwait: Situation Update," January 27, 1991.
[30] Central Intelligence Agency, "Iraqi Capabilities and Intentions to Use Chemical Weapons," undated.
[31] Defense Intelligence Agency, Defense Security Assessment 181A-91, "Iraq-Kuwait: Situation Update," January 27, 1991.

chemical warhead in 1990, and that Iraq had stockpiled 150 Scuds with chemical warheads.[18] The Defense Intelligence Agency (DIA) judged that these warheads would most likely contain persistent chemical warfare agents such as VX (nerve agent) or mustard (blister agent).[19] However, another report quotes an Iraqi engineer who claimed to have worked on the Al Hussein and Al Abbas missile programs. This engineer stated that Iraq still had not succeeded in manufacturing chemical warheads for its ballistic missiles and that Saddam Hussein's threat to launch Scuds with chemical warheads at Israel was "a mere poker game."[20]

According to an intelligence source, the Al Hussein missile could carry either chemical warfare (CW) or biological warfare (BW) warheads. Iraq could mount a biological agent warhead on the Al Abbas version of the Scud. This source reported Iraq planned to use cholera for biological warfare against targets in the Gulf region (but weaponization of cholera could not be verified later).[21]

Intelligence agencies may have put less emphasis on Scuds as a biological threat, but they considered that threat real. The Central Intelligence Agency (CIA) assessed:

> We have no information to confirm that Iraq has developed or manufactured BW warheads for its ballistic missiles. However, Iraq has the ability to weaponize its BW agents—including anthrax spores—and we believe it is well within Iraq's technical capabilities to produce BW warheads for its Scud missiles.... It probably would take only one BW warhead to neutralize any one given target. Our analysis indicates that the Al Husayn [alternate spelling], carrying about 100 kilograms (KG) of dried anthrax spores, would theoretically produce a maximum area of lethal contamination of 1,600 square kilometers [579 square miles]. That would be a dispersion area about 90 KM long and 15 KM wide at the widest point [56 by 9 miles]. Other of Iraq's BW agents would be equally potent: Botulinus toxin would produce a maximum lethal area of contamination of about 21 square kilometers [8 square miles] and anthrax spores in solution would produce an area of about 110 square kilometers [42 square miles].... Iraq only needs a few BW-tipped missiles in its stockpile to cause significant casualties.[22]

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[18] Central Intelligence Agency, "Report on Iraqi Chemical/Nuclear Warhead Systems," 1991.
[19] Defense Intelligence Agency, "Scud Chemical Agent Coverage Patterns - Aug 90," August 1990.
[20] Kagan, Mark H., "Iraq's Case: The International Missile Trade and Proliferation," The International Missile Bazaar: The New Suppliers' Network, William C. Potter and Harlan W. Jencks, eds., Westview Press, Boulder, Colorado, 1994.
[21] Defense Intelligence Agency, "Daily Training Schedule at Mukhabarat," undated; United Nations Special Commission, "UNSCOM's Comprehensive Review," Annex C, Status of Verification of Iraq's Biological Warfare Programme, January 29, 1999, web site: www.un.org (as of April 25, 2000).
[22] Central Intelligence Agency, "Iraq CW," undated.

that Iraq did experiment with UDMH,[12] but this investigation found no evidence that Iraq switched to UDMH during the Gulf War.

To extend the Scud's range, Iraq cut Scud Bs apart and inserted airframe sections from these missiles into other Scud Bs to increase the capacities of the fuel and oxidizer tanks from about 8,700 pounds to about 11,000 pounds.[13] Iraq also reduced warhead weight from 2,200 pounds to less than 1,100 pounds. (See Table 1 above.)

In 1991, Iraq had three kinds of mobile Scud launchers for its operational Scud models.[14] Other support vehicles included cranes, separate tanker trucks for fuel and oxidizer, command and control vans, and missile resupply vehicles.[15]

Iraq's modifications to the Scud Bs created flight stability problems. Unlike more modern ballistic missile designs, the Scud's warhead does not detach from the rest of the missile after the boost phase (the period when the rocket motor fires and accelerates the missile). The missile body reenters the atmosphere still attached to the warhead. The changes in the center of gravity and weight distribution between the modified warhead and missile body, plus the added speed and subsequent increase in atmospheric heating during reentry, made the missiles unstable and often caused them to disintegrate before impact. Such break-ups degraded accuracy by changing missile trajectory. Iranian reports about Al Hussein attacks during the Iran-Iraq war noted that the missiles frequently broke into pieces. Coalition and Israeli reports about Gulf War Scud attacks contained similar observations (see Section V below).

IV. SCUDS AND CHEMICAL AND BIOLOGICAL WEAPONS

The evidence clearly shows that Saddam Hussein eventually intended to field operational Scuds armed with chemical and biological warheads, and he committed substantial resources to that end.[16] However, did Iraq successfully achieve that goal by the time of Operation Desert Storm?

A. Threat Estimates Before Operation Desert Storm

Information from before the Gulf War generated serious concern among Coalition forces about Iraq's possible use of Scuds armed with chemical or biological warheads. Pre-war intelligence judged that Iraq might have chemical warheads for Scuds.[17] One source said that despite very unstable flight characteristics, Iraq successfully completed development of a Scud with a

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[12] Central Intelligence Agency Nonproliferation Center fact sheet, "The Russian Scud B," undated; Federation of American Scientists, "UNSCOM and Iraqi Missiles," web site: www.fas.org (as of May 13, 1999).

[13] Carus, Seth W. and Joseph S. Bermudez, Jr., "Iraq's Al-Husayn Missile Programme," *Jane's Soviet Intelligence Review*, May 1990, p. 204.

[14] Jane's Information Group, "Al Hussein," *Jane's Strategic Weapon Systems 1995-96*, September 16, 1996.

[15] Zaloga, Steven, "Ballistic Missiles in the Third World," *International Defense Review*, November 1988, p. 1427; Centre for Defence and International Security Studies, "1990: The Iraqi Scud Threat," web site: www.cdiss.org (as of September 24, 1997).

[16] Central Intelligence Agency, "Iraq and the Gulf War, 1990-91," undated.

[17] Defense Intelligence Agency, "Chemical and Biological Warfare in the Kuwait Theater of Operations; Iraq's Capability and Posturing," undated.

target area.[7] Consequently, Scuds had notoriously poor accuracy, and the farther they flew, the more inaccurate they became.[8]

Table 1 reflects key data on Iraq's ballistic missiles including the Scud B acquired from the USSR and the three variants produced by Iraq by modifying the original Scud configuration.

Table 1. Characteristics of Iraq's selected missiles[9]

	Scud B	Al Hussein	Al Abbas	Al Hijarah
Length (ft.)	36.8	41	47.6	Unknown
Diameter (in.)	35	35	35	Unknown
Warhead Wt (lbs.)	2,200	1,100	308-550	About 550
Max Range (mi.)	186	373+	500-560	Iraq claimed 466
Accuracy (CEP)[10] (mi.)	0.62	1-2	1.9-3.1	Unknown
Gulf War Involvement	None fired	All but 5 fired were this model	Development stopped in 1990 – none fired	Iraq claimed 5 fired

All of Iraq's Scuds used kerosene as the fuel and some form of red fuming nitric acid, probably inhibited red fuming nitric acid (IRFNA)[11] as the oxidizer. Iraq told the United Nations Special Commission inspectors after the war that they had not experimented with unsymmetrical dimethylhydrazine (UDMH), a more powerful (and toxic) fuel than kerosene, for their Scuds, which would require engine redesign. However, inspectors subsequently uncovered evidence

[7] Jane's Information Group, "Al Hussein," *Jane's Strategic Weapon Systems 1995-96*, September 16, 1996.
[8] Central Intelligence Agency, "IZ Chemical and Biological Warhead Threat," undated.
[9] Lenhart, Warren W. and Todd Masse, "Persian Gulf War: Iraqi Scud Ballistic Missile Systems," Congressional Research Service report to Congress, February 14, 1991, p. CRS-2, CRS-5-7; Federation of American Scientists, Nuclear Forces Guide, "al-Abbas," web site: www.fas.org (as of May 13, 1999); Centre for Defence and International Security Studies, "National Briefings: Iraq," web site: www.cdiss.org (as of July 29, 1999); Centre for Defence and International Security Studies, "Iraq's Ballistic Missile Capabilities," web site: www.cdiss.org (as of July 29, 1999); Department of Defense message, subject "IIR 2 340 2823 91/Information on Mines, Missiles and NBC Weapons," 011735Z Mar 91; Cordesman, Anthony H., "Weapons of Mass Destruction in the Middle East," Brassey's, London, 1991, p. 40, 45-46; Defense Intelligence Agency, "Daily Training Schedule at Mukhabarat," undated; Carus, Seth W. and Joseph S. Bermudez, Jr., "Iraq's Al-Husayn Missile Programme," *Jane's Soviet Intelligence Review*, May 1990, p. 205; Jane's Information Group, "Al Hussein," *Jane's Strategic Weapon Systems 1995-96*, September 16, 1996; Center for Nonproliferation Studies, "Weapons of Mass Destruction in the Middle East," web site: cns.miis.edu (as of April 24, 2000).
[10] Circular error probable. See glossary at Tab A.
[11] Defense Intelligence Agency, Report, Subject: "Reference Task OICC 4139, Orange Cloud Assessment," redacted, February 4, 1991.

The Soviet Union provided Iraq with Scuds mounted with conventional warheads during the 1970s and 1980s.[3] During its war with Iran, Iraq first developed modified or "stretched" Scuds, resulting in the Al Hussein model, with enough propellant and range to reach Iran's capital of Tehran. Because Baghdad is closer to the Iran-Iraq border than Tehran, Iran was able to reach Baghdad from much closer range with their own Scuds and did not need longer-range missiles. The Al Hussein closed the "missile gap." During the seven-week "war of the cities" in early 1988, Iraq's Scuds rained terror on Tehran and other Iranian cities while Iran used unmodified Scud Bs against Baghdad and other targets in Iraq. Iraq's missiles with high explosive warheads killed about 2,000 Iranians and injured 6,000. Over a quarter of the population of ten million fled Tehran. In April of 1988, Iran ended its Scud attacks on Iraq and subsequently negotiated for peace.[4] In the wake of his success with the modified Scud, Saddam Hussein sought further improvements with the Al Abbas and the Al Hijarah models.

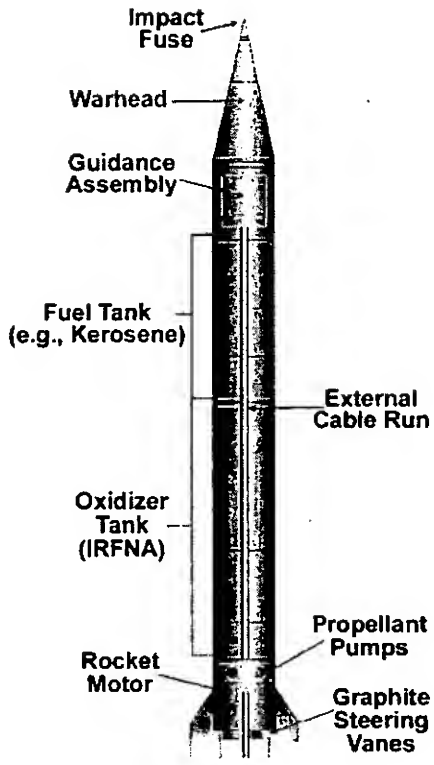

Figure 1. Iraq's Scud missile components[5]

III. IRAQ'S SCUD CHARACTERISTICS AND CAPABILITIES

Coalition forces knew the ballistic missiles that Iraq developed from Soviet Scud Bs as "Scuds," regardless of Iraq's Arabic names for their longer-range variants. For this reason, we have used the same shorthand in this paper. Iraq fired mainly the Al Hussein model at the Kuwait theater of operations and Israel.

Figure 1[5] diagrams the basic components of Iraq's Scuds. Regardless of the variants—original Scud B, Al Hussein, Al Abbas, or Al Hijarah—all of Iraq's Scuds were liquid fueled, short-range ballistic missiles with a crude guidance system. Unsophisticated gyroscopes guided the missile only during powered flight—which lasted about 80 seconds for the Al Hussein variant.[6] Once the rocket motor shut down, the entire missile with the warhead attached coasted unguided to the

[3] Carus, Seth W. and Joseph S. Bermudez, Jr., "Iraq's Al-Husayn Missile Programme," *Jane's' Soviet Intelligence Review*, May 1990, p. 204.
[4] Jane's Information Group, "Strategic Delivery Systems," *Jane's Intelligence Review*, June 1995, p. 18; Carus, Seth W. and Joseph S. Bermudez, Jr., "Iraq's Al-Husayn Missile Programme," *Jane's Soviet Intelligence Review*, June 1990, p. 242-244.
[5] Based on Central Intelligence Agency Nonproliferation Center fact sheet, "The Russian Scud B," undated.
[6] Lennox, Ducan, "Inside the R-17 'Scud B' Missile," *Jane's Intelligence Review*, July 1991, p. 302, 304; Central Intelligence Agency memorandum, subject "Consolidated SCUD Comments," April 18, 2000, p. 3.

I. SUMMARY

Iraq began launching short-range ballistic missiles (known as Scuds) at Israel and Coalition forces soon after the Coalition's Gulf War air campaign began on January 17, 1991. Many Gulf War veterans observed or became aware of incoming or overflying Scud missiles, Patriot missiles fired in defense, and Scud missile or debris impacts. American and other Coalition forces in the Kuwait theater of operations knew that Iraq had the capability to use chemical and biological weapons, and Scud missile attacks represented a significant cause for concern for anyone within their range.

This Information Paper offers a primer on Scud missiles and describes Iraq's use of Scuds during the Gulf War. The paper also briefly reviews topics related to counter-Scud operations, including Patriot missile defenses.

Iraq filled both chemical and biological warheads for their Scud missiles before the Gulf War. However, Iraq probably feared retaliation if they used them. In-depth research for this paper uncovered no hard evidence that Iraq fired Scuds with chemical or biological warheads during the Gulf War. All Scud debris analyzed indicated use of conventional warheads.

Iraq's Scud attacks involved 88 missiles, of which 46 reached Coalition countries in the Kuwait theater of operations and 42 reached or closely approached Israel. A few more probably failed early in flight and struck within Iraq's borders. Iraq told United Nations inspectors after the war that they launched 93 ballistic missiles, 50 against the Coalition in the Kuwait theater of operations and 43 against Israel. Scuds, while inaccurate, nonetheless damaged area targets and caused 28 of the 148 United States battle deaths during the Gulf War. Scuds often broke up on reentry, dispersing propellant that sometimes caused burning sensations of the skin and throat, nausea, headaches, breathing difficulties and other symptoms in some United States servicemembers. Also, Scud attacks and precautionary alerts disrupted lives and operations by forcing passive defense measures and generating stress.

II. HISTORICAL BACKGROUND[1]

The North Atlantic Treaty Organization (NATO) used the nickname "Scud B" when referring to the Soviet-made, mobile, single-stage, single-warhead, liquid-fueled, short-range ballistic missile (originally designated by the Soviets as the R-17). Within the intelligence community, it also carried the designation SS-1c (SS for surface-to-surface). The Soviets developed this missile from an earlier version (Scud A) fielded in the 1950s, which they based in turn on the infamous German V-2 of World War II. The Scud B model first appeared with Soviet operational forces in 1962.[2]

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[1] Tab A provides acronyms, abbreviations, and a glossary.

[2] Lennox, Ducan, "Inside the R-17 'Scud B' Missile," *Jane's Intelligence Review*, July 1991, p. 302; University of Michigan Computer Club, "Soviet Operational Missiles and Rockets," web site www.umcc.edu (as of July 27, 1999).

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Information Paper

Iraq's Scud Ballistic Missiles

Information Papers are reports of what we know today about military equipment and/or procedures used in the 1990-1991 Gulf War. This particular information paper on Iraq's Scud ballistic missiles is not an investigative report, but is meant to provide the reader with a basic understanding of the characteristics, capabilities, and employment of Iraq's Scuds. This is an interim, not a final paper. We hope that you will read this and contact us with any information that would help us better understand Iraq's Scud ballistic missiles and more accurately report their use during the Gulf War. Please contact my office to report any new information by calling:

1-800-497-6261

Bernard Rostker
Special Assistant for Gulf War Illnesses
Department of Defense

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Last Update: July 25, 2000

Many veterans of the Gulf War have expressed concern that their unexplained illnesses may result from their experiences in that war. In response to veterans' concerns, the Department of Defense established a task force in June 1995 to investigate incidents and circumstances relating to possible causes. The Office of the Special Assistant to the Deputy Secretary of Defense for Gulf War Illnesses assumed responsibility for these investigations on November 12, 1996, and has continued to investigate topics related to reports of chemical warfare agent incidents.

To inform the public about the progress of these efforts, the Department of Defense is publishing on the Internet and elsewhere accounts that may contribute to the discussion of possible causes of illnesses of Gulf War veterans, along with documentary evidence or personal testimony used in compiling the accounts. This information paper will aid in understanding incidents involving Iraq's use of Scud missiles.

TAB D – Changes in this Report

This narrative was initially published on August 19, 1997. Since that time, the Office of the Special Assistant for Gulf War Illnesses has not received any new information on the material presented here, nor have any additional leads developed to change the narrative's assessments. Additionally, the Presidential Special Oversight Board reviewed the narrative and recommended that the Office of the Special Assistant republish it as final. The only changes that have been made to the paper are:

- The narrative has been rewritten to reflect the updated methodology and footnoting standards of the Office of the Special Assistant for Gulf War Illnesses.
- Some new source documents have been referenced to enhance the accuracy of the narrative.
- Sections discussing "Analysis" and "Lessons Learned" have been added.

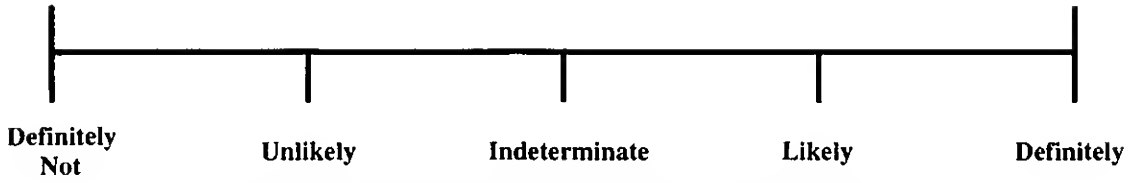

Figure 3. Assessment of chemical warfare agent presence

The standard for making the assessment is based on common sense: Do the available facts lead a reasonable person to conclude that chemical warfare agents were or were not present? When insufficient information is available, the assessment is Indeterminate until more evidence can be found.

mind-set of those involved, and are particularly important if physical evidence is lacking. Nuclear, biological, and chemical officers or specialists trained in chemical testing, confirmation, and reporting are interviewed to identify the unit's response, the tests that were run, the injuries sustained, and the reports submitted. Commanders are contacted to ascertain what they knew, what decisions they made concerning the events surrounding the incident, and their assessment of the incident. Where appropriate, subject matter experts also provide opinions on the capabilities, limitations, and operation of technical equipment, and submit their evaluations of selected topics of interest.

Additionally, the investigator contacts agencies and organizations that may be able to provide additional clarifying information about the case. These would include, but not be limited to:

- Intelligence agencies that might be able to provide insight into events leading to the event, imagery of the area of the incident, and assessments of factors affecting the case;
- The clinical registries of the Departments of Defense and Veterans Affairs which may provide data about the medical condition of those involved in the incident; and
- Agencies capable of computer modeling meteorological and source characterization data in cases where airborne dispersion of agent is suspected.

Once the investigation is complete, the investigator evaluates the available evidence in order to make a subjective assessment. The available evidence is often incomplete or contradictory and thus must be looked at in the total context of what is known about the incident being investigated. Physical evidence collected at the time of the incident, for example, can be of tremendous value to an investigation. Properly documented physical evidence would generally be given the greatest weight in any assessment. The testimony of witnesses and contemporaneous operational documentation is also significant when making an assessment. Testimony from witnesses who also happen to be subject matter experts is usually more meaningful than testimony from untrained observers. Typically, secondhand accounts are given less weight than witness testimony. When investigators are presented with conflicting witness testimony, they look for other pieces of information supporting the statements of the witnesses. Investigators evaluate the supporting information to determine how it corroborates any of the conflicting positions. Generally, such supporting information will fit into a pattern corroborating one of the conflicting accounts of the incident over the others. Where the bulk of corroborating evidence supports one witness more than another, that person's information would be considered more compelling.

Our assessments rely on the investigators' evaluation of the available information for each investigation. Because we do not expect to always have conclusive evidence, we have developed an assessment scale (Figure 3) ranging from Definitely Not to Definitely, with intermediate assessments of Unlikely, Indeterminate, and Likely. The investigator will use this scale to make an assessment based on facts available as of the date of the report publication. This case has been reassessed over time based on new information and feedback.

A case usually starts with a report of a possible chemical warfare agent incident, often from a veteran. To substantiate the circumstances surrounding an incident, the investigator searches for documentation from operational, intelligence, and environmental logs. This focuses the investigation on a specific time, date, and location, clarifies the conditions under which the incident occurred, and determines whether there is "hard," as well as anecdotal, evidence.

Alarms alone are not considered to be certain evidence of chemical warfare agent presence, nor is a single observation sufficient to validate a chemical warfare agent presence. The investigator

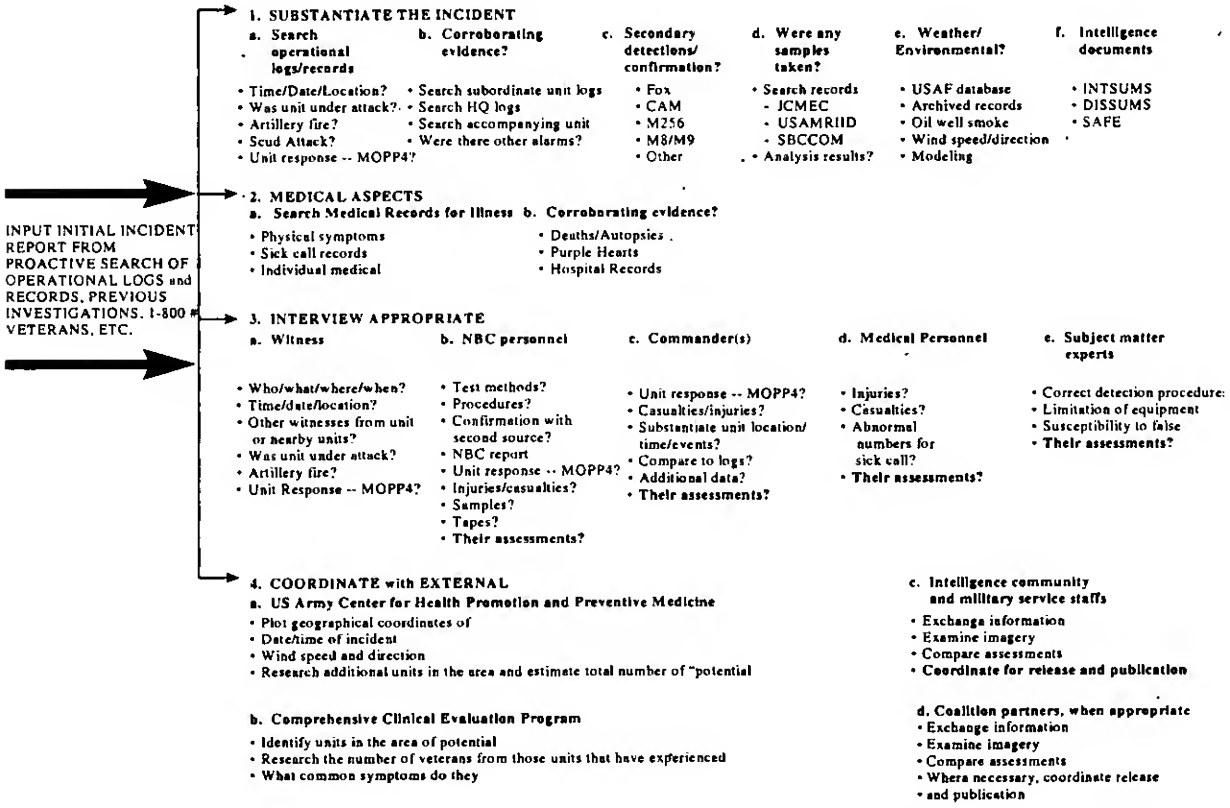

Figure 2. Chemical warfare incident investigation methodology

looks for physical evidence collected at the time of the incident that might indicate that chemical agents were present in the vicinity of the incident. Such evidence might include tissue samples, body fluid samples, clothing, environmental samples of soil or vegetation, weapons parts, and Fox MM-1 tapes with properly documented spectrums.

The investigator searches available medical records to determine if anyone was injured by the incident. Deaths, injuries, sicknesses, etc., near the time and location of an incident are noted and considered. Medical experts are asked to provide information about any alleged chemical warfare agent casualties.

Interviews of those involved in or near the incident (participants or witnesses) are conducted. First-hand witnesses provide valuable insight into the conditions surrounding the incident and the

TAB C – Methodology For Chemical Warfare Incident Investigation

The Department of Defense requires a common framework for our investigations and assessments of chemical warfare agent reports, so we turned to the United Nations and the international community, which had chemical weapons experience (e.g., the United Nations' investigation of the chemical weapons used during the 1980-88 Iran-Iraq war). Because the modern battlefield is complex, the international community developed investigation and validation protocols[29] to provide objective procedures for possible chemical weapons incidents. The methodology we are using is based on these international protocols and guidelines. The methodology includes:

- A detailed written record of the conditions at the site;
- Physical evidence from the site such as weapons fragments, soil, water, vegetation, or human or animal tissue samples;
- A record of the chain of custody during transportation of the evidence;
- The testimony of witnesses;
- Multiple analyses; and
- A review of the evidence by an expert panel.

While the methodology used to investigate chemical incidents (Figure 2) is based on these protocols, the passage of time since the Gulf War makes it difficult to obtain certain types of documentary evidence, and physical evidence often was not collected at the time of an event. Therefore, we cannot apply a rigid template to all incidents, and each investigation must be tailored to its unique circumstances. Accordingly, we designed our methodology to provide a thorough investigative process to define the circumstances of each incident and determine what happened. The major efforts in our methodology are:

- To substantiate the incident;
- To document available medical reports related to the incident;
- To interview appropriate people;
- To obtain information available to external organizations; and
- To assess the results.

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[29] "Convention on the Prohibition of the Development, Production, Stockpiling, and Use of Chemical Weapons and on Their Destruction," April 29, 1997. This chemical weapons convention was opened for signature in Paris, France, on January 13, 1993. It has been signed by 165 states and ratified or acceded by 106 states as of February 1998. It was signed by the United States on January 13, 1993, and ratified on April 25, 1997. Part XI of the convention, "Investigations in Cases of Alleged Use of Chemical Weapons," details some of the procedures. Other protocols and guidelines were found in Methodology and Instrumentation for Sampling and Analysis in the Verification of Chemical Disarmament, The Ministry for Foreign Affairs of Finland, Helsinki, Finland, 1985; Verification Methods, Handling, and Assessment Of Unusual Events In Relation To Allegations of the Use of Novel Chemical Warfare Agents, Consultant University of Saskatchewan in conjunction with the Verification Research Unit of External Affairs and International Trade Canada, March 1990; and Handbook for the Investigation of Allegations of the Use of Chemical or Biological Weapons, Department of External Affairs, Department of National Defence, Health and Welfare Canada, and Agriculture Canada, November 1985. US Army Field Manual 3-4, US Marine Corps Fleet Marine Force Manual 11-9, "NBC Protection," May 1992; US Army Field Manual 8-285, US Navy NAVMED P-5041, US Air Force Manual 44-149, US Marine Corps Fleet Marine Force Manual 11-11 (adopted as NATO Field Manual 8-285), "Treatment Of Chemical Agent Casualties and Conventional Military Chemical Injuries," December 22, 1995; US Army Field Manual 19-20, "Law Enforcement Investigations," November 25, 1985; and other DoD investigational procedures contributed ideas for developing this methodology.

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Leachates	A leachate is the material removed from a sample during chemical analysis.[26]
Mass Spectrometry	This is a method of identifying the chemical constitution of a substance by means of the separation of gaseous ions according to their differing mass and charge – called also mass spectroscopy.[27]
Nuclear Magnetic Resonance	The phenomenon in which atomic nuclei spin around the axis of a strong magnetic field. The spinning nuclei create oscillating magnetic fields and emit a detectable amount of electromagnetic radiation.[28]

[26] Merriam Webster's Online Dictionary, web site www.m-w.com (as of July 13, 2000).
[27] Merriam Webster's Online Dictionary, web site www.m-w.com (as of July 13, 2000).
[28] Stedman's Concise Medical Dictionary for the Health Professions, 3rd edition., ed. John H. Dirckx, M.D., Baltimore, Maryland, Williams & Wilkins, 1997, [on Compact Disk].

TAB A – Acronyms, Abbreviations, and Glossary

This tab provides a listing of acronyms and abbreviations found in this report. Additionally, the glossary section provides definitions for selected technical terms that are not found in common usage.

Acronyms and Abbreviations

CBDCOM.....Chemical and Biological Defense Command

ERDEC.....Edgewood Research and Development Engineering Center

IRFNA.....Inhibited Red Fuming Nitric Acid

PAC.....Presidential Advisory Committee

PGIIT..... Persian Gulf Illnesses Investigation Team

US.....United States

Glossary

Chemical Ionization	Chemical ionization is a process used to create molecules that have either a positive or negative charge.[21]
Chromatography	The separation of chemical substances and particles by differential movement through a two-phased system.[22]
Gas Chromatography	The sample mixture is vaporized in gas chromatography. The process by which a vaporized mixture is separated into its component compounds.[23]
High Performance Liquid Chromatography	A chromatographic technology used to separate and measure mixtures of substances in solution.[24]
Ion Chromatography	Ion chromatography is a form of liquid chromatography that uses ion-exchange resins to separate atomic or molecular ions based on their interaction with the resin.[25]

[21] Iowa State University, web site www.cif.iastate.edu/MassSpec/ci.html (as of July 11, 2000).
[22] Stedman's Concise Medical Dictionary for the Health Professions, 3rd edition, ed. John H. Dirckx, M.D., Baltimore, Maryland, Williams & Wilkins, 1997, [on Compact Disk].
[23] Merriam-Webster's Online Dictionary, web site www.m-w.com (as of July 13, 2000).
[24] Stedman's Concise Medical Dictionary for the Health Professions, 3rd edition, ed. John H. Dirckx, M.D., Baltimore, Maryland, Williams & Wilkins, 1997, [on Compact Disk].
[25] Scimedia, web site scimedia.com/chem-ed/sep/lc/ion-chro.htm (as of March 17, 2000).

taken from a test sample spiked with mustard agent.[11] "All nuclear magnetic resonance and gas chromatography/mass spectrometry tests [were] negative."[12] The scientists who analyzed the sample wore protective gloves and worked in a ventilated laboratory. This is routine safety procedure for conducting these analyses. We did not attempt to duplicate the reported scenario that created the symptoms, and the scientists were not exposed to the unprotected sample and, therefore, were unable to verify the reported symptoms.

The PGIIT also arranged for the Missile and Space Intelligence Center to perform a metallurgical analysis of the sample to determine its source; the piece was found to be consistent with the metallurgical properties of Scud missiles.[13] The veteran who provided the sample to the PAC also reported that he independently submitted two other portions of the metal fragment to two commercial laboratories, but the laboratories refused to handle the material and returned them.[14] The veteran was informed of all test results.[15]

IV. ANALYSIS

When reviewing the circumstances of this case, the investigator analyzed three key issues:

- **What was the origin of the sample?** Since the Missile and Space Intelligence Center's metallurgical tests on a portion of the metal fragment determined that it possessed characteristics aligned with the properties of Scud missiles, we accept that the metal fragment is a piece of a Scud missile.[16]
- **What was the chain of custody for the sample?** During a meeting on September 18, 1995, the Presidential Advisory Committee (PAC) received a small metal fragment from someone in the audience. This person stated that the fragment came from a soldier stationed at King Fahd Military Airport on January 19, 1991. The soldier told him that

[11] Edgewood Research and Development Engineering Center, Memorandum, Subject: "Analysis of Metal Scrap Final Report," December 12, 1995; Edgewood Research and Development Engineering Center, Hand-written results of analysis signed by analyst, October 13, 1995; Chemical and Biological Defense Command, Email, Subject: "DISUM," October 19, 1995; Edgewood Research and Development Engineering Center, Analytical Chemistry Team, Subject: "Analysis Metal Scrap: OTH22395," October 5, 1995; Edgewood Research and Development Engineering Center, File on Sample #OTH22395, November 1996.

[12] Edgewood Research and Development Engineering Center, Memorandum, Subject: "Analysis of Metal Scrap Final Report," December 12, 1995; Edgewood Research and Development Engineering Center, Hand-written results of analysis signed by analyst, October 13, 1995; Chemical and Biological Defense Command, Email, Subject: "DISUM," October 19, 1995; Edgewood Research and Development Engineering Center, Analytical Chemistry Team, Subject: "Analysis Metal Scrap: OTH22395," October 5, 1995; Edgewood Research and Development Engineering Center, File on Sample #OTH22395, November 1996.

[13] United States Army, Missile Command Structures Directorate, Memorandum, Subject: "Analysis of Sample (Steel Fragment) (U)," June 2, 1994.

[14] Persian Gulf Illnesses Investigation Team, Memorandum, Subject: "Scud Piece Referred to PGIT by [Redacted] for Analysis," December 20, 1996.

[15] Persian Gulf Illnesses Investigation Team, Memorandum, Subject: "Request from [Redacted]," December 8, 1995; Deputy Assistant Secretary of Defense (Clinical Services), Letter, July 15, 1996; Persian Gulf War Veterans' Illnesses Investigation Team, Letter, May 2, 1996.

[16] United States Army, Missile Command Structures Directorate, Memorandum, Subject: "Analysis of Sample (Steel Fragment) (U)," June 2, 1994.

VI. LESSONS LEARNED

The key lesson expressed throughout this investigation is that soldiers should not pick up battlefield souvenirs or artifacts. Items on the battlefield may contain contaminants or present other safety hazards that are not immediately obvious.

This is a final report. However, if you believe you have information which may change this case narrative, please contact my office by calling 1-800-497-6261.

this was a Scud fragment. He also stated that the soldier had stored it in a plastic bag and forgotten about it, until he rediscovered it in August 1994. He then gave it to the person who provided it to the PAC.[17] Since (reportedly) the soldier who initially found the fragment in 1991 cannot account for it from the time he stored it in a plastic bag until its rediscovery in August 1994, we cannot establish the chain of custody before its presentation to the PAC.

- **Did the sample contain elements indicating the presence of chemical warfare agents?** The US Army Edgewood Research and Development Engineering Center's nuclear magnetic resonance and gas chromatography/mass spectrometry tests for the presence of chemical warfare agents on the sample were negative.[18] The sample did not contain any indication of chemical warfare agents.[19] Although the tests yielded no chemical warfare agents, the report does not preclude the possibility of other toxic substances on the Scud piece. For example, Iraq's Scuds were propelled by a combination of kerosene and a toxic oxidizer, inhibited red fuming nitric acid (IRFNA), which was reported to have caused irritations and injuries during the Gulf War.[20] However, the veteran did not report symptoms that indicated IRFNA presence, and the lab did not test for possible contamination by IRFNA or its by-products, so we can make no assessments about IRFNA presence.

V. ASSESSMENT

Since the chemical analysis has shown no evidence of the presence of chemical warfare agents, we assess that it is unlikely that a chemical warfare agent existed on the Scud sample. Because we cannot attest to the chain of custody before the Presidential Advisory Committee received the sample nor can we confirm the reported symptoms due to exposure to the sample, the assessment is unlikely rather than definitely not.

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[17] Department of the Army, Deputy Chief of Staff Intelligence, Foreign Materiel Program, Memorandum, Subject: "[Redacted] Scud Missile," October 3, 1995.

[18] Persian Gulf Illnesses Investigation Team, Memorandum, Subject: "Request for Analytical Support," December 5, 1995.

[19] Edgewood Research and Development Engineering Center, Memorandum, Subject: "Analysis of Metal Scrap Final Report," December 12, 1995; Edgewood Research and Development Engineering Center, Hand-written results of analysis signed by analyst, October 13, 1995; Chemical and Biological Defense Command, Email, Subject: "DISUM," October 19, 1995; Edgewood Research and Development Engineering Center, Analytical Chemistry Team, Subject: "Analysis Metal Scrap: OTH22395," October 5, 1995; Edgewood Research and Development Engineering Center, File on Sample #OTH22395, November 1996.

[20] For information on Iraq's Scud missile program and the effects of IRFNA, see Special Assistant for Gulf War Illnesses, "Scud Information Paper" (Information Paper), July 25, 2000, web site www.gulflink.osd.mil/scud_info/; and Special Assistant for Gulf War Illnesses, "Inhibited Red Fuming Nitric Acid (Information Paper), August 3, 1999, web site www.gulflink.osd.mil/irfna/.

hour, there is a watery blister; and within three to four hours, there is a large blister. The blister will rupture on its own in six to seven hours.[3]

The Persian Gulf Illnesses Investigation Team[4] (PGIIT) reviewed reports of Scud missile attacks near King Fahd Military Airport during the period of January 12-26, 1991. Veterans who called the Veterans Reporting Hotline have reported Scud alerts near King Fahd Military Airport during that general period.[5] The only Scud activity on January 19, 1991, (the date the soldier reported the Scud intercept) was four missiles fired from Iraq toward Tel Aviv, Israel.[6] However, available data suggests Iraq launched missiles toward Dhahran (located near King Fahd Military Airport) on January 20-21, 1991.[7] Patriot missiles intercepted these Scuds, so we assume that this sample came from the Scud attack on the evening of January 20 or early morning of January 21.

The PAC gave the sample to the Department of Defense Foreign Materiel Program, which in turn arranged for the US Army Edgewood Research and Development Engineering Center (ERDEC) to test for the presence of any known chemical warfare agents.[8] ERDEC did a thorough analysis of the metal piece using gas chromatography/mass spectrometry, nuclear magnetic resonance, high performance liquid chromatography/ion chromatography, and chemical ionization.[9] "They found no compounds in either of the leachates [material removed from a sample during chemical analysis] of the piece of metal submitted for analysis."[10] To further test its findings, ERDEC also analyzed the spectra taken from the fragment and spectra

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[3] Department of the Army, Deputy Chief of Staff Intelligence, Foreign Materiel Program, Memorandum, Subject: "[Redacted] Scud Missile," October 3, 1995.

[4] The Persian Gulf Illnesses Investigation Team is the predecessor organization to the Office of the Special Assistant for Gulf War Illnesses, Investigation and Analysis Directorate.

[5] Incident Report 459001155 Incident Description: Scud Alerts near King Fahd Military Airport, September 13, 1995, and Incident Report 459001166 Incident Description: Scud Alerts near King Fahd Military Airport, September 14, 1995.

[6] Department of the Army, Deputy Chief of Staff Intelligence, Foreign Materiel Program, Memorandum, Subject: "[Redacted] Scud Missile," October 3, 1995; and Ninth US Air Force Air Combat Command, "Special Study of the 347th's Participation in Desert Shield/Desert Storm: January - December 1991, Volume I," June 30, 1992.

[7] Air Force, Defense Special Missile and Astronautics Center, Message: Serial Number S/DQ/148-81, February 27, 1991; Unidentified United States Central Command organization, "Scud Launch/Kill Summary;" 82nd Airborne Division, "Daily Staff Journal or Duty Officer's Log," January 21, 1991.

[8] Persian Gulf Illnesses Investigation Team, Memorandum, Subject: "Request for Analytical Support," December 5, 1995.

[9] Edgewood Research and Development Engineering Center, Memorandum, Subject: "Analysis of Metal Scrap Final Report," December 12, 1995; Edgewood Research and Development Engineering Center, Hand-written results of analysis signed by analyst, October 13, 1995; Chemical and Biological Defense Command, Email, Subject: "DISUM," October 19, 1995; Edgewood Research and Development Engineering Center, Analytical Chemistry Team, Subject: "Analysis Metal Scrap: OTH22395," October 5, 1995; Edgewood Research and Development Engineering Center, File on Sample #OTH22395, November 1996.

[10] Edgewood Research and Development Engineering Center, Memorandum, Subject: "Analysis of Metal Scrap Final Report," December 12, 1995; Edgewood Research and Development Engineering Center, Hand-written results of analysis signed by analyst, October 13, 1995; Chemical and Biological Defense Command, Email, Subject: "DISUM," October 19, 1995; Edgewood Research and Development Engineering Center, Analytical Chemistry Team, Subject: "Analysis Metal Scrap: OTH22395," October 5, 1995; Edgewood Research and Development Engineering Center, File on Sample #OTH22395, November 1996.

insufficient information is available, the assessment is Indeterminate until more evidence can be found.

II. SUMMARY

On September 18, 1995, a veteran submitted a small metal sample to the Presidential Advisory Committee for analysis and to determine if it was contaminated by chemical warfare agents. The veteran reported that the sample was given to him by another soldier who identified it as a piece of a Scud missile intercepted by a Patriot missile near King Fahd Military Airport on or about January 19, 1991. Analysis of the sample by the US Army Edgewood Research and Development Engineering Center revealed no evidence of chemical warfare agents. The assessment for this case is that chemical warfare agent presence is unlikely. Because we cannot attest to the chain of custody before the Presidential Advisory Committee received the sample nor can we confirm the reported symptoms due to exposure to the sample, the assessment is unlikely rather than definitely not.

III. NARRATIVE[1]

On September 18, 1995, during a meeting in Charlotte, North Carolina, the Presidential Advisory Committee (PAC) on Gulf War Veterans' Illnesses received a small piece of metal.[2] The veteran who provided this sample reported that the soldier who found it told him that it was a piece from a Scud missile intercepted by a Patriot missile near King Fahd Military Airport on January 19, 1991. He further reported the following chain of custody: a soldier from King Fahd Military Airport picked up the metal piece as a souvenir; the soldier stored the fragment in a plastic bag, he forgot about it for more than three years; and subsequently, he rediscovered it in August 1994 in Charlotte, North Carolina. This soldier then gave the piece to the veteran who provided a portion of it to the PAC.

The veteran described the original piece of the Scud as being about six inches long, five inches wide, about 3/8 inches thick, and burned on both sides. The veteran who provided the sample told an investigator from the Army's Foreign Materiel Program (Office of the Deputy Chief of Staff for Intelligence) that:

> The unprotected sample, when examined in an enclosed room with no ventilation, will cause a person's eyes to water after about 10 minutes and sometimes will cause a tingly sensation. Additionally, touching the sample will cause a burning sensation within about 10 minutes on the contacted skin. Within 20 minutes, the area is red; within 30 minutes, there is a slight ring around the red part; within an

[1] Tab A contains acronyms, abbreviations, and a glossary.

[2] Department of the Army, Deputy Chief of Staff Intelligence, Foreign Materiel Program, Memorandum, Subject: "[Redacted] Scud Missile," October 3, 1995; Persian Gulf Illnesses Investigation Team, Status Report, Subject: "Scud Missile Part," no date; Office of the Assistant Secretary of Defense (Health Affairs), Letter, November 2, 1995.

I. METHODOLOGY

One prominent hypothesis about illnesses among Gulf War veterans is that some of the reported symptoms are the result of exposure to chemical warfare agents. During and after the Gulf War, some veterans reported that they had been exposed to chemical warfare agents. To investigate these incidents, and to assess the likelihood that chemical warfare agents were present in the Gulf, the Department of Defense developed a methodology for investigation and validation based on work done by the United Nations and the international community. The criteria include:

- A detailed written record of the conditions at the site;
- Physical evidence from the site such as weapons fragments, soil, water, vegetation or human/animal tissue samples;
- A record of the chain of custody during transportation of the evidence;
- The testimony of witnesses;
- Multiple analyses; and
- A review of the evidence by experts.

While the methodology (Tab C) used to investigate suspected chemical warfare agent incidents is based on these protocols, the passage of time since the Gulf War makes it difficult to obtain certain types of documentary evidence, and physical evidence was often not collected at the time of an event. Therefore, we cannot apply a rigid template to all incidents, and each investigation must be tailored to its unique circumstances. Accordingly, we designed our methodology to provide a thorough investigative process to define the circumstances of each incident and to determine what happened. Alarms alone are not considered to be certain evidence of chemical warfare agent presence, nor is a single observation sufficient to validate the presence of a chemical warfare agent.

After following our methodology and accumulating anecdotal, documentary, and physical evidence; after interviewing witnesses and key servicemembers; and after analyzing the results of all available information, the investigator assesses the validity of the presence of chemical warfare agents on the battlefield. Because we do not expect to always have conclusive evidence, we have developed an assessment scale (Figure 1) ranging from Definitely Not to Definitely, with intermediate assessments of Unlikely, Indeterminate, and Likely. This assessment is our best judgement, based on facts available as of the date of the report publication. This case has been reassessed over time based on new information and feedback.

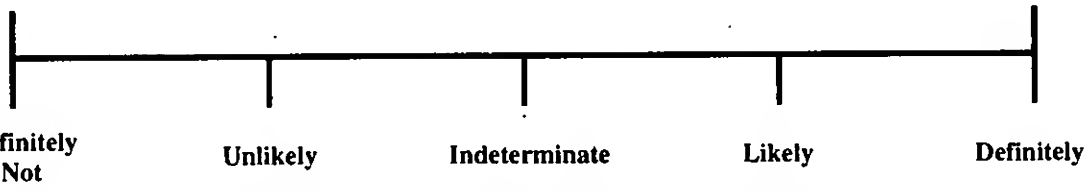

Figure 1. Assessment of chemical warfare agent presence

The standard for making the assessment is based on common sense: Do the available facts lead a reasonable person to conclude that chemical warfare agents were or were not present? When

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Case Narrative

Possible Chemical Agent On Scud Missile Sample

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Many veterans of the Gulf War have expressed concern that their unexplained illnesses may result from their experiences in that war. In response to veterans' concerns, the Department of Defense established a task force in June 1995 to investigate those incidents and circumstances relating to possible causes. The Office of the Special Assistant to the Deputy Secretary of Defense for Gulf War Illnesses assumed responsibility for these investigations on November 12, 1996.

Case Narratives are reports of what we know today about specific events that took place during the Gulf War of 1990 and 1991. This particular case narrative focuses on the analysis of a piece of a Scud missile that a veteran provided to the Presidential Advisory Committee on Gulf War Veterans' Illnesses, and which he reported caused symptoms similar to exposure to certain chemical warfare agents. The narrative was initially published on August 13, 1997. Since that time, the Office of the Special Assistant for Gulf War Illnesses has not received any new information that contradicts the material presented, nor have any additional leads developed to change the narrative's assessments. Additionally, the Presidential Special Oversight Board for Department of Defense Investigations of Gulf War Chemical and Biological Incidents reviewed the narrative and recommended that the Office of the Special Assistant republish it as final. For this reason, this is a final report. However, if you believe you have information that may change this case narrative, please contact my office by calling:

1-800-497-6261

Bernard Rostker
Special Assistant for Gulf War Illnesses
US Department of Defense

Case Narrative

Possible Chemical Agent On Scud Missile Sample

Final Report

July 25, 2000

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